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Uzbekistan Energy Efficiency in Urban Water Utilities in Central Asia

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JOINT UNDP / WORLD BANK

ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAMME (ESMAP)

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Table of Contents

List of Figures

Preface

The following study was undertaken as part of the Energy Sector Management Assistance Program (ESMAP) thematic work on energy efficiency. The objective was to evaluate Energy Efficiency in Urban Water Utilities to test the common assumption that there existed an enormous energy reduction potential in the water utilities in the Former Soviet Union and more specifically in Central Asia. The study focused on the historic cities of Samarkand and Bukhara in Uzbekistan.

Consulting services were hired for site surveys, for testing equipment systems, for implementing energy efficiency evaluation methods, and for recommending specific investment strategies for the Bukhara and Samarkand City Water and Wastewater Utilities. The energy efficiency evaluation method utilizes an innovative approach and technology.

The report includes a detailed description of the water supply & distribution facilities found in Bukhara and Samarkand, the conditions of the works identifying low energy efficiency, a detailed analysis of the efficiency tests performed to pumps of the Water Utilities in these cities, an energy usage assessment including the performance indicators, and investment recommendations and a dissemination program incorporating final recommendations to reduce energy consumption by the cities water systems.

The approach taken for the study and its conclusions can be highly beneficial for other water utilities that need improved energy efficiency, not only in Uzbekistan, but in other countries of the Soviet Union where approximately 95% of the energy used by water facilities is attributed to the pumping equipment and the energy reduction potential is viable if a water loss reduction program is implemented in the region, and in other water utilities in developing countries. The financial benefits of reduction in the very large energy consumption levels in these utilities can be substantial and are the main motivator to implement these recommendations.

The task manager of this study was Ede Jorge Ijjaz-Vasquez. The report was edited by Grammarians. Special thanks to Ms. Nidhi Sachdeva for formatting this report and to Ms. Marjorie K. Araya for coordinating the publication process.

List of Tables

Executive Summary

1 The infrastructure in Uzbekistan is generally in a very poor condition. The water supply infrastructure in the two cites investigated, Samarkand and Bukhara are no exceptions. The water supply systems were installed during the time of the former Soviet Union some thirty years ago. Whilst the designs were not excellent, they were probably appropriate for that time, albeit somewhat high on energy consumption. In recent years and certainly since the collapse of the Soviet Union the condition of the water supply infrastructure has deteriorated substantially.

2 Although everyone talks about the enormous energy reduction potential of water utilities in the Former Soviet Union in general and Central Asia in particular, very little is known about the ***actual*** energy reduction potential. This is troublesome for two reasons:

a. It is nearly impossible to set realistic (achievable but yet challenging) targets for Management Contracts; and

b. The economic benefit of major pump replacement programs is unknown.

3 Furthermore it is not only the infrastructure replacement which matters - the motivation of the workforce and the availability of essential tools and spare parts are important issues too.

Key Conclusions

4 As a result of this consultancy, several key conclusions can be drawn:

- Over 95% all of the energy use is related to pumping plant, therefore other energy uses and inefficiencies are relatively minor.
- The energy reduction potential of individual pumps varies widely and thus a detailed analysis will always be needed.
- Most of the Bukhara pumpsets are incorrectly sized for the operating duty, resulting in poor efficiency and in some cases overload of the motors.
- Some pumps are throttled to prevent motor overload, reducing pump efficiency. This can be avoided by correctly sizing the motor, or by trimming the pump impeller.
- Many of the pumps could probably be refurbished and adjusted by a pump manufacturer to better meet the operating duty and improve efficiency but others are best replaced.

- The poor efficiency of the large horizontal pumps at the treatment works and the borehole pumps in Samarkand is largely due to worn out pump internals.

- The installation of Western “High Tech” pumps is troublesome as spare parts are expensive and difficult to procure for Uzbek Vodokanals.

- Motor rewinds are very frequent, averaging around once per year for some pumps, indicating that the Vodokanals are not procuring high quality rewinds, which should last for 10 years. Although the individual rewinds may be relatively cheap, this is not a cost effective operation and poor rewinds also reduce motor efficiency.

- An increase in reliability of plant would enable the currently excessive amount of standby plant to be scrapped, reducing the maintenance burden and further enhancing reliability by simplifying the system.

- Pumping station buildings are generally in poor condition and should be refurbished using local labour. In particularly, urgent attention should be given to sealing leaking roofs.

- A water loss reduction program will reduce energy usage in the pumping stations.

Pump Efficiency Test Results

5 Tables 1 and 2 below summarize the results of the pump efficiency tests in Bukhara and Samarkand. These tables are shaded to indicate the condition of the pumps and the potential for pump refurbishment.

Table 1: Summary of Pump Efficiency Test Results – Bukhara

Station Name	Pump No	Duty Point		Current Normal Operating Point:				Current Best Efficiency Point:		As-New Pump Efficiency:		Shortfall From Expected Efficiency
		Head (m)	Flow (m3/h)	Head (m)	Input Power (kW)	Pump Eff'y (%)	Flow (m3/h)	BEP Flow (m3/h)	BEP Eff'y (%)	Optimal	Expected (-5%)	
Source of Data		Vodokanal	Vodokanal	Measured	Measured	Computed	Computed	Determined from tests	Determined from tests	Computed	Computed	Computed
Kuymazar Final	2	62	2500	33	459.6	55.6	2748	2122	72.9	88.3	83.3	-12.5
Kuymazar Final	3	62	2500	34.4	518.8	52.9	2833	2020	80.2	88.3	83.3	-3.7
Kuymazar Final	5	75	3200	60.4	742	65.5	2871	2454	71	88.3	83.3	-14.8
Kuymazar Final	6	100	2000	100.9	868.7	60.2	1860	2259	63.5	88.3	83.3	-23.8
Zaravshan Final	6	65	1000	56.4	331.6	68.6	1401.8	1126.8	72.9	87.0	82.0	-11.1
Zaravshan Final	3	65	500	46.9	204.1	37.4	558.3	422.0	48.6	84.4	79.4	-38.8
Zaravshan Intake	1	30	1800	11.3	86.2	61.3	1605.8	1458.5	66.2	87.7	82.7	-20.0
Zaravshan Intake	2	30	1800	13.5	99.7	70.5	1787.5	1565.9	73.1	87.7	82.7	-11.6
Shohrud Intermediate	2	30	5000	15.3	508	69.7	8069	9209	71.4	90.5	85.5	-16.5
Shohrud Final	1	75	3200	71.5	813.4	66.6	2701.2	3161	67.6	88.9	83.9	-19.4
Shohrud Reserve	2	65	1500	20.3	322.4	35.7	1981.7	1410	76.2	88.9	83.9	-9.2
Shohrud Final	3	65	1500	28.2	306.7	42.1	1599.6	975.6	63.3	88.9	83.9	-24.6
Shohrud Final	5	75	3200	48.1	843.2	57.4	3609	3329	61.3	89	84	-27.0
Shohrud Final	7	75	3200	39.8	703.9	65.3	4116	2849	75.9	88.9	83.9	-9.5

Key to table shading:

Pump condition and potential for refurbishment:

satisfactory	fair	poor

Table 2: Summary of Pump Efficiency Test Results – Samarkand

Station Name	Pump	Duty Point		Current Normal Operating Point:				Current Best Efficiency Point:		As-New Pump Efficiency:		Shortfall from Expected Efficiency
		Head (m)	Flow (m3/h)	Head (m)	Input Power (kW)	Pump Eff'y (%)	Flow (m3/h)	BEP Flow (m3/h)	BEP Eff'y (%)	Optimal	Expected	
Source of Data		Vodokanal	Vodokanal	Measured	Measured	Computed	Computed	Determined from tests	Determined from tests	Computed	Computed	Computed
Chupanata Well Field	14	30	255	15.7	35.7	37.4	257.3	257.3	41	68	63	-34.9
Chupanata Well Field	15	30	255	14.3	36.7	25.7	185.4	185.4	29.5	68	63	-53.2
Chupanata Well Field	17	30	255	10.7	26.9	29.1	195.1	195.1	41.2	68	63	-34.6
Chupanata Final PS	1	95	4000	85.1	1301.4	83.5	4574.6	4282.9	83.9	89.5	84.5	-0.7
Dahbed Well Field	1	30	255	25.2	29.8	44.8	194.4	194.4	44.8	68	63	-28.9
Dahbed Well Field	2	30	255	25	37.6	44.8	260.6	128	50	68	63	-20.6
Dahbed Well Field	4	30	255	23.9	31.2	47.3	148.7	148.7	31	68	63	-50.8
Dahbed Final	2	125	1250	106.4	649.2	71.5	1535.6	1353.7	72.9	87.5	82.5	-11.6
Dahbed Final	3	125	1250	116.1	613.2	64	1189.3	1093.9	65.2	87.5	82.5	-21.0
Dahbed Final	5	95	4000	134.2	604.8	69.5	1102.1	1322.8	72.9	87.5	82.5	-11.6
Dahbed Final	6	125	1250	104.7	714.7	67.9	1630.6	1386.6	71	87.5	82.5	-13.9
Moulien	2	55	3200	49.0	381.5	77.2	2128.1	1955.3	78	88.2	83.2	-6.3
Moulien	4	55	3200	36.9	382.7	56.8	2089.4	1790.2	73.4	88.0	83.0	-11.6
Sogdiana Booster	2	63	500	63	128.9	66.5	466.7	424.4	67.1	84.5	79.5	-15.6
Sogdiana Booster	3	70	720	69.4	139.5	67.4	465.4	420.2	68	84.5	79.5	-14.5
Micorayon Booster	3			56.1	83.5	54	272	184.8	63.7	82.1	77.1	-17.4
Micorayon Booster	5			51.4	291.7	51.7	1016.1	812.2	66.3	86.3	81.3	-18.5

Energy Efficiency Performance Indicator

6 The concept of performance based Management Contracts requires clearly determined performance standards and targets, which the operator has to achieve. Since energy reduction is always an important issue, the selection of an appropriate indicator is crucial.

7 It is necessary to use an indicator which only measures the efficiency gains of pumping stations - irrespectively with other developments (leakage reduction and supply improvement).

8 The most appropriate and internationally recognized (IWA[1]) performance indicator relevant to pumping plant efficiency is:

Indicator Ph4 (Standardized energy consumption)**: Wh/m^3 at 100m**

Annual energy consumption for pumping Σ (volume elevated x pump head in hundreds of meters)

9 Using this indicator, it will be possible to set challenging but achievable targets for the operator and accurately monitor the related performance.

10 The results of an Energy Efficiency Study, similar to this one, will be sufficient to determine the percentage figure for the improvement (=reduction) of Indicator Ph4 from baseline. However, it will not be possible to baseline all plant before accurate flow and pressure measurement equipment is installed at all pumps. Therefore, a methodology is detailed in the report that initially relies on estimation of the present Ph4 indicator using the data collected during the study to estimate achievable improvements. When the necessary metering is available, the initial estimate can be updated, based on measured data.

11 This approach has been applied to estimate the achievable efficiency improvements in Bukhara and Samarkand:

[1] Alegre H., Hirner W., Baptista J.M. and Parena R. (2000) Performance Indicators for Water Supply Services. IWA Manual of Best Practice. ISBN 900222272

Table 3: Energy Reduction Potential – PH4 Indicator - Bukhara

Bukhara		Present Annual Energy Consumption [MWh]	**Estimated Average Ph4 [Wh/m3 at 100m]**	
			Actual	Future
Kuamazar	Final	23,900	482	430
Zaravshan	Final	2,550	599	430
Zaravshan	Intake	850	444	430
Shokrud	Intermediate	3,452	411	411
Shokrud	Final	11,048	564	430
Ph4 Weighted Average			**504**	**428**
Reduction			**15%**	

12 At present, Bukhara has an estimated weighted average of 504 Wh/m3 at 100 m. By implementing the suggested improvement measures in Kuamazar, Zaravshan and the Final pumps at Shokrud (assuming that all of them will afterwards be in the range of 430), the overall average Ph4 will be in the range of 428 Wh/m3 at 100 m - a reduction of 15% (see Table 3). The annual split of these 15% (for example 5, 10 and 15 % reductions from baseline during year 2, 3, and 4) will of course depend on the implementation schedule.

13 An even bigger reduction (see Table 4) potential can be found in Samarkand, where Ph4 could be reduced by as much as 28 % (from 577 to 414) - simply by changing all pumps in the two well fields.

Table 4: Energy Reduction Potential – PH4 Indicator - Samarkand

Samarkand		Present Annual Energy Consumption [MWh]	**Estimated Average Ph4 [Wh/m3 at 100m]**	
			Actual	Future
Chupanata	Well	12,909	937	430
Chupanata	Final	25,891	401	401
Dahbed	Well	8,657	937	430
Dahbed	Final	17,043	417	417
Moulien	Booster	2,650	431	431
Sogdiana	Booster	609	435	435
Microrayon	Booster	670	553	553
Ph4 Weighted Average			**577**	**414**
Reduction			**28%**	

14 Using this indicator, international comparisons will also be possible - Bristol Water's system for example has a Ph4 of around 385 Wh/m3 at 100m, which might be slightly above average UK water utilities.

Summary of Findings

15 In the following section, the Consultant has tried to summarise the findings and conclusions, but it is strongly recommended to examine the test result data in detail.

16 In the city of Samarkand, the Vodokanal has very little money for essential tools let alone spare parts. The Vodokanal owes a considerable sum in unpaid electricity bills and workers salaries are often delayed or not paid in full. This financial difficulty is reflected in the motivation of the workers and the poor condition of the water supply equipment.

17 The position of Vodokanal Bukhara is a little better, with a less complicated water supply system. It also has an apparently more stable management and probably a little better motivated employees. It has a slightly better financial position but like Samarkand there is insufficient money for quality spare parts or good motor rewinds and certainly not for replacement of large pumps.

18 The availability of spares and access to support from manufactures are essential in maintaining equipment to a good standard. This report recommends an investment program to meet the availability of finance and is based on the condition of the existing equipment. The investment program and the type of investment is summarized in Table 5 .Of particular concern is the recruitment, motivation and retention of a skilled maintenance workforce; this can only be achieved with satisfactory and reliable salaries. These issues should be considered at the same time

as the capital investment. There is little point in recommending all new equipment only for it to require replacement in ten years time through lack of appropriate care and maintenance.

Table 5: Summary of Recommended Investments

City	Plant	Pumpset	No of Units	Investment Type	Investment Cost (US$)
Bukhara	Shokrud	Final & Switchgear	4	Replacement	1,200,000
Bukhara	Shokrud	Intermediate	2	Refurbishment, New motor	60,000
Bukhara	Zaravshan	Final	3	Refurbishment, New motors	155,000
Bukhara	Zaravshan	Intake	2	Refurbishment	30,000
Bukhara	Ku Mazar	Intake	6	Refurbishment	180,000
Bukhara	All plants	Flow & pressure monitoring	7 sets	New installation	140,000
Bukhara	Ku Mazar	Intake	6	New motors	240,000
Bukhara	Ku Mazar	Switchgear, cabling	1 set	Replacement	1,100,000
Bukhara	Zaravshan	Switchgear, cabling	1 set	Replacement	250,000
Samarkand	Dahbed	Well	30	Replacement	510,000
Samarkand	Chupanata	Well	57	Replacement	969,000
Samarkand	Mouleon	Booster	1	Remove blockage	1,000
Samarkand	Dahbed, Chupanata	Flow & pressure monitoring	6 sets	New installation	120,000
Samarkand	Distribution	Boosters	6 sets	Replacement	1,800,000
Samarkand	Dahbed	Final	4	Replacement	1,600,000

19 When investing in energy reduction measures, it is tremendously important to carefully analyze the available options. The Consultant has analyzed the investment options relating to energy efficiency improvements in the two Cities - and the results are surprising - a summary is given in Table 6.

20 Whilst it is obvious that the well pump-sets in Samarkand clearly have by far the worst efficiency (37% below what could realistically achieved) and the annual saving would be more than US$50,000, about US$1.5 M would have to be invested. Consequently the internal rate of return (IRR) after 10 years is –15.5%.

21 In comparison, the simple refurbishment and trimming of the pumps in Ku Mazar (Bukhara), which have only an efficiency shortfall of 15%, has an IRR after 10 years of 10.9%, by far the best of all options.

Table 6: Summary - Cost Efficiency[2] of Investment Options

City	Plant	Efficiency Shortfall [%]	Investment Cost [US$]	Energy Saving [kWh/yr]	Cost Saving [US$/yr]	IRR (After 10 years)	Cost Saving (At UK Energy Prices) [US$/yr]	IRR (At UK Energy Prices) (After 10 years)
Bukhara	Shokrud	18.3%	1,260,000	2,657,971	23,866	-22.6%	152,745	12.9%
Bukhara	Zaravshan	20.1%	185,000	685,396	6,787	-15.0%	43,435	21.9%
Bukhara	Ku Mazar	15.2%	180,000	3,628,112	30,380	10.9%	194,431	132.0%
Samarkand	Well Pumps	**37.1%**	1,479,000	6,197,026	52,232	-15.5%	334,285	20.7%
Samarkand	Booster Pumping Stations	16.9%	1,800,000	372,009	4,903	-39.2%	31,378	-23.3%
Samarkand	Dahbed Final	13.0%	1,600,000	2,646,840	36,854	-20.5%	235,866	9.0%

22 The replacement of all booster pumps in Samarkand (an option which was frequently discussed during the preparation of the Management Contract), on the other hand is certainly the least economical investment, with an IRR after 10 years of –39.2% (note: this is partly related to the present limited operating time).

23 With the exception of the refurbishment of the pumps at Ku Mazar, none of the other investments analyzed in Table 6 could be justified on the basis of improving energy efficiency, with the current very low energy costs in Uzbekistan, although they are recommended as infrastructure improvements. However, it is unlikely that energy prices in Uzbekistan will in the future remain at the existing low levels. The impact of increases in energy prices on the IRR is illustrated in Table 6 by including an assessment of the IRR assuming that energy prices in Uzbekistan increased to UK prices (average of $0.054/KWh). If energy prices increased to this level, all but one of the proposed investments could be justified on the basis of energy efficiency improvements.

24 In general, the strategy chosen is to retain many of the existing Russian made split casing centrifugal pump-sets which can be easily maintained by the Uzbek workforce and which would be a relatively high cost to replace.

25 However, in certain cases pump replacement is recommended. In these cases, care should be taken in drafting the specifications for new plant to take into account the limited maintenance facilities, general access to international support, present technical ability and operating budget in the Vodakanals. The emphasis should be on

[2] Note: All estimates are based on current electricity prices (at the time this report was prepared) and an exchange rate of 700 Sum for 1 US$

simple or otherwise proven very reliable equipment. Automation should generally be limited to plant protection only. A specification for an axially split casing pump has been included in the report to provide an example of an appropriate specification.

26 Opportunity should be taken to use local labour at a competitive cost to renovate the buildings at an early stage in the investment program.

27 Table 7 gives an overview of the investments suggested for Bukhara whilst summarizes the Investments in Samarkand.

Table 7: Summary - Investments Bukhara

Location	Equipment	Number	Refurbishment/New	Estimated Cost (US$)
Priority Investment				
Ku Mazar Intake	Raw water pump sets	6	Refurbish & Trim to duty	180,000
Shokrud Treatment Works	Final water pumps & Electrical Switchgear	4	All New	1,200,000
Shokrud Treatment Works	Intermediate Final pump- sets	1 2	New Motor, Refurbish & Trim to duty	30,000 30,000
Zarapshan Treatment Works	Final pumps	2 2	New Motor Pumps Replaced by refurbished Shohkrud pumps	80,000 30,000
Zaravshan Treatment Works	Final pump No. 6	1 1	New Motor Refurbish & Trim to duty	30,000 15,000
Zaravshan Treatment Works	Intake pumps	2	Refurbish & Trim to duty	30,000
Ku Mazar, Shokrud, Zaravsahan	Flow & Pressure Monitoring	7 sets	New Installation	140,000
TOTAL				**1,765,000**
Medium Term Investment				
Ku Mazar Intake	Raw water pump sets	6	Motor	240,000
Ku Mazar Intake	Electrical switchgear & Cabling	1 set	New, Complete High Voltage Switchboard with six motor starters	1,100,000
Zaravshan Treatment Works	Electrical switchgear & Cabling	1 set	New, Complete High Voltage Switchboard with motor starters	250,000
TOTAL				**1,590,000**
Priority & Medium Term Investment				**3,355,000**

Table 8: Summary - Investments Samarkand

Location	Equipment	Number	Refurbishment/New	Estimated Cost (US$)
Priority Investment				
Dahbed	Well pumps	30	New	510,000
Chupanata	Well pumps	57	New	969,000
Mouleon	Booster Pump	1	Local Labour	1,000
Chupanata & Dahbed	Flow & Pressure Monitoring	6 sets	New Installation	120,000
TOTAL				**1,600,000**
Medium Term Investment				
Six Distribution Booster Pumping Stations	Two Variable Speed pumps operating in Duty/Standby mode	6 sets of differing duties	New	1,800,000
Dahbed	Pumpset & Electrical Equipment	4 sets	New	1,600,000
TOTAL				**3,400,000**
Priority & Medium Term Investment				**5,000,000**

The New Pumps in Samarkand - Lessons to be learned

28 A substantial investment has already been made in new Ingersoll/ABB pump-sets at Chuponata Treatment works ("French Project"). The Vodokanal management and maintenance staff are very concerned they will not be able to keep this equipment well maintained. They have poor access to support services speaking Russian, they have insufficient money to purchase spare parts at western prices and they have little experience, and possibly ability, in maintaining the relatively sophisticated switchgear, control and monitoring equipment now installed. At the time of the field mission in April 2002, a motor protection device had failed. A new one was requested and sent from France. It remains unfitted and an expensive, new pump-set stands idle, because the Vodokanal was unable to afford the customs clearance fee.

29 Labour is cheap in Uzbekistan. Whilst technicians may not have the abilities of their western counterparts they are able to operate and maintain traditional plant, especially if they can get good technical support in their own language. With strong technical management and support they could progress to more sophisticated systems in due course. Presently, sophistication is unjustified. The new computer based telemetry system for monitoring the well pumps at Chuponata is an excellent piece of engineering. But unfortunately, it probably does not substantially improve the level of service or reduce costs. Indeed if maintained correctly it will actually increase costs – western sourced spare parts are in Uzbekistan terms very expensive. Presently the Vodokanal cannot even afford a quality motor rewind from a reputable contractor in their own country.

30 New equipment specifications should require that telephone technical support and manuals are available in Russian and that the delivery logistics and costs of spares are detailed in the equipment supplier's proposal document. Similarly the arrangements for site support visits and training should be detailed and costed.

Metering and Tariffs

31 The consultancy also considered the accuracy of metering and electricity tariffs. The following summarizes the findings in these areas.

- It was not possible during this consultancy to check the accuracy of the Electricity Utility's meters, as this would have entailed shutting down treatment works. However, if the Vodokanals installed their own check meters, they may show that the billing meters are under-recording energy usage.
- There is a single day tariff with no differentiation between daytime and nighttime electricity usage, although there are different tariffs for high voltage and low voltage supplies and for supply capacities above 750 kW.
- A pumped storage scheme would offer opportunities to reduce energy costs in Samarkand by maximizing night pumping, if it is possible to negotiate appropriate time of day tariffs with the Electricity Utility. However, this would require construction of an additional service reservoir, using local labour, on the hills on the outskirts of Chuponata.
- A charge is made for the capacity of the electricity supply provided and in some cases the electrical load would seem to exceed the declared supply capacity, so the Vodakanals might be paying slightly less than could be demanded of them.

Recommendation on Combined Studies

32 Experience gained during the preparation of the Management contracts in Tajikistan, Kazakhstan and Uzbekistan showed that the following engineering studies are needed to prepare the budget for the rehabilitation fund and to set meaningful annual performance targets:

- Water production, consumption and water loss (Non-Revenue Water) assessment.
- Pressure monitoring program to determine present supply continuity.
- Energy efficiency study.
- Water production, treatment and quality assessment.

33 Execution of these four studies in parallel has several disadvantages:

- Optimum timing will be difficult (recruitment of Consultants, mobilization, availability), thus it is likely that that the overall duration will be substantially more than the maximum duration (6 months) of the longest individual study.

- Frequent overlapping:

  - between Leakage and Energy Study: flow measurements at all production facilities, equipment rent and transport;

  - between Leakage and Pressure Study: pressure measurements and equipment rent and transport, familiarisation with the distribution system;

  - between Pressure and Energy Study: pressure measurements close to pumping stations, equipment rent and transport;

  - between Water Quality and Energy Study: condition of pumps and equipment in treatment plants and wells.

- Different project teams will have to familiarize themselves with the situation. Thus the Client will frequently have to answer the same questions several times. Constructive co-operation with counterpart staff will become increasingly difficult.

- Conclusions to be drawn are in many cases related on the results of more than one study. The subjects are heavily interrelated.

- Total costs are high. The examples given above add up to US$565.000. Out of that, a substantial amount is spent on project management, travel, equipment rent.

34 The Client might get confused: different Consultants might come up with very different recommendations. Consistency in the approach is not guaranteed. Client and Legal Consultants will have to deal with a too many specialists during preparation of the RFP document. Further delays are programmed.

35 Combining all of the above-mentioned studies into one offers obviously substantial benefits. Reduced cost (sees below) is one of them, but reduced implementation time and more comprehensive and integrated results, recommendations and performance targets are of even greater importance.

36 Assuming that the study has to be carried out for a similar system, its duration and cost were estimated as follows:

Total Timeframe:	6 months
Field works:	3 months
Manpower Input:	12 man months

Total Cost: US$350,000

37 The advantages of the combined study are obvious. Lessons learned during all the individual studies carried out during the last three years should form the basis for the elaboration of model Terms of Reference.

1

The Mission

Background

1.1 The Energy Sector Management Assistance Program (ESMAP) has provided funds for an evaluation program of Energy Efficiency in Urban Water Utilities in Central Asia. A portion of the funds is used for **Consulting Services for Site Surveys and Testing of Equipment and Systems and Elaboration, of Energy Efficiency Evaluation Methodology, Improvement and Specific Investment Strategies for the Bukhara and Samarkand City Water and Wastewater Utilities.**

1.2 The consulting services to be covered by the project relate specifically to the development of Energy Efficiency Evaluation Methodology, Improvement and Specific Investment Strategies for Bukhara Vodokanal (BVK) and Samarkand Vodokanal (SVK), including a limited set of strategic on-site surveys, testing and monitoring of equipment and installations, and an overall system energy efficiency evaluation.

1.3 The lack of actual operational data in water utility implies that a targeted measurement program will be required to locate and quantify the energy inefficiencies in the system and to prioritize the recommended interventions. The energy efficiency evaluation of the water supply systems will include all key components, particularly the treatment plant components with highest energy consumption, major pumping stations, block-level pumping stations, reservoirs, equipment, electrical connections, maintenance practices, pumping schedule, and energy metering, among others.

1.4 This report is the **Final Report** for the above-mentioned project and presents the results of visits made between 10th February and 23rd April 2002. Messrs James Reckhouse, John Whittaker and Andreas Stoisits conducted the field visits and are also the authors of this report for BWS.

1.5 The scope of work of the consulting services according to the Terms of Reference can be roughly in four main elements, as follows:

- **Element A:** Testing of network pumping stations (major pumping stations, block-level pumping stations, etc.) and preparation of high priority respectively medium term investments for an energy efficiency program
- **Element B:** Testing of pumps on water production facilities (treatment plants for surface water, and well fields) and preparation of high priority respectively medium term investments for an energy efficiency program
- **Element C:** Proposal for monitoring indicators and targets of energy efficiency for the utility operator to be hired under a Service Contract.
- **Element D:** Capacity building and on-time dissemination activities for know how transfer with regard to energy audits and savings programs.

Energy Efficiency Testing - Element A & B

1.6 During the Inception Mission information was obtained on the pumping plant installed in the Cities of Samarkand and Bukhara and an understanding gained of how the systems are operated. All treatment works and large raw water pumping stations were visited in both cities. From this information it was determined which plant would be efficiency tested and which aspects of the equipment and operation warranted more detailed consideration. The pumps chosen were those which use the most energy.

1.7 It had been intended to test twenty pumps in each city. At the time of the visit in April some of the pumps that had been identified for testing had failed – usually due to burnt out motors.

1.8 In Bukhara all sites and tappings had been fitted prior to arrival of the consultants. In Samarkand the Vodokanal had not fitted any tappings to the well pump-sets pipework prior to the visit as requested. These were subsequentially procured and fitted under the supervision of BWS/AEMS.

1.9 Where possible the system curve for the pumped system was determined and the duty of the present pumps compared with this.

Bukhara

1.10 A total of **fourteen pumpsets were tested**. This was a representative sample of the pumps at Shokhrud and Zaravshan Treatment Works and Ku Mazar raw water pumping station.

Ku Mazar

1.11 At Ku Mazar raw water pumping station there are eight pumpsets of various duties are in operation. Two of the pumpsets are for irrigation duties the remainder supply Shokhrud treatment works. **Four** of the pumpsets supplying Shokhrud were tested. Two had burnt out motors and the Chief Engineer advised that as the irrigation pumpsets were operated by others it was not appropriate to test them.

Shokhrad

1.12 At Shokhrud treatment works **five** final water pumpsets**,** and **one** intermediate pumpsets were tested. This was essentially as planned except that an intermediate pumpset was tested in place of an intake pumpset.

Zaravshan

1.13 At Zaravshan treatment works **two** final water pumpsets, and **two** higher duty intake pumpsets were tested. It had been hoped to test more final water pumpsets but only two were available.

Samarkand

1.14 A total of **seventeen pumpsets were tested**. This was a representative sample of the pumps at Chuponata and Daghbed Treatment Works and the network booster stations.

Chuponata

1.15 Chuponata has the highest energy usage of all the pumping stations in either Samarkand or Buckahara

Well Pumpsets

1.16 There are fifty-two identical well pumpsets. **Three** of these were tested to determine efficiency.

Final Water Pumpsets

1.17 There are four final water pumpsets. These are modern European units installed in 2000. **One** of these was tested.

Dahbed

Well Pumpsets

1.18 There are twenty-five identical well pumpsets**. Three** well pumpsets were tested to determine efficiency as planned. These well pumpsets are identical to those installed at Chuponata.

Final Water Pumpsets

1.19 There are six final water pumpsets. **Four** were tested.

- **Moulien Network Pumping Station**

At Moulien Network Pumping Station there are three pumpsets. **Two** pumpsets were tested.

- **Micorayon Network Pumping Station**

At Mircorayon Network Pumping Station there are only two working pumpsets. **Two** pumpsets were tested.

- **Sogdiana Network Pumping Station**

At Sogdiana Pumping Station there are three pumpsets. **Two** pumpsets were tested.

Monitoring Indicators - Element C

1.20 It is understood that the International Operator for the Vodokanals will be required to control energy costs. Indicators are required to enable the change in energy efficiency and consumption to be monitored. Targets are required to drive the operator to improve on the present position. Monitoring indicators must be based on truly measurable and specific quantities. Targets must be practical and achievable.

Dissemination Activities - Element D

1.21 Workshops were held in both Bukhara and Samarkand at the end of the testing work. The workshops took the form of three power point presentations backed up with ad-hoc explanations/diagrams on flip charts. There were three sessions in a day in each Vodokanal.

1.22 At all stages during the pump testing activities, Vodokanal staff were involved and care was taken to explain to them exactly what was being done and why. Opportunity was taken to discuss plant operation with Vodokanal staff at all levels and to impart the concepts of energy efficient operation. The use of two interpreters considerably aided smooth dialogue with operatives and enabled everyone to get the most from the consultant's visit.

1.23 More details are given in Chapter 8 of this report. The slides used in workshop presentations are attached in the Appendix B.

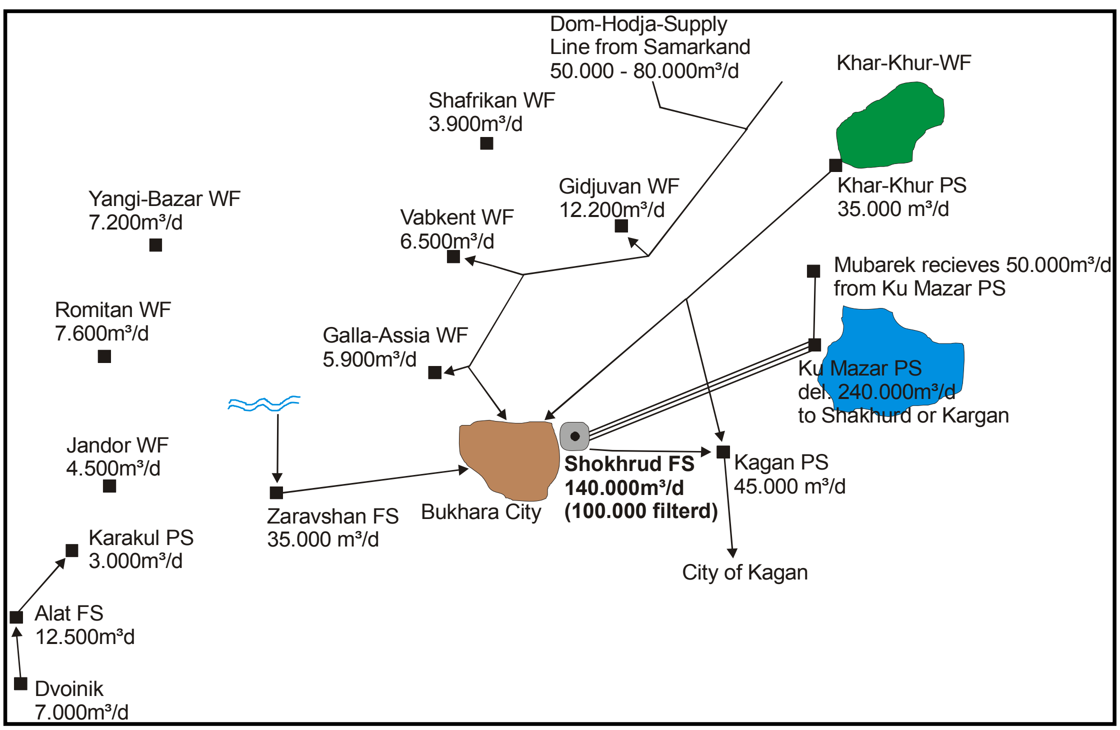
2

Description of Water Supply & Distribution Facilities

Bukhara

2.1 Bukhara city has a population in the order of 260,000. Treatment works at Shokhrud and Zaravshan supply the majority of the water to the city. The raw water pumping station at Ku Mazar some 35 km to the NE of the Bukhara feeds the Shokhrud treatment works and also an irrigation network. Some water is also received via the Dom Hodja water supply pipeline and is pumped from the Shokhrud final water pumping station. The raw water for the Zaravshan treatment plant is sourced from the Amu-Bukhara Channel. Figure 2.1 outlines the key features of the distribution system in Bukhara.

Figure 2.1: Schematic Layout of Pumping Stations and Reservoirs - Bukhara



Pumping stations at Water Sources and Treatment works

2.2 The open reservoir **Ku Mazar** supplies raw water to Shokhrud treatment works and also water to the irrigation company for agricultural purposes. In total eight pumps are installed in Ku Mazar raw water pumping station.

2.3 There are two treatment works supplying the city of Bukhara, called Shokhrud and Zaravshan.

2.4 **Shokhrud** treatment works has a nominal production capacity of 100,000 m^3/day although on occasions this may reach over 140,000 m^3/day. The water is sourced from the Ku Mazar reservoir. Treatment is rapid gravity filtration and marginal chlorination. The super-chlorinated water is produced on site by electrolysis and injected into a contact/balance tank to mix with the main process flow. The filtration process is often bypassed due to operating difficulties resulting in poor water quality.

2.5 **Zaravshan** treatment works has a nominal production capacity of 35,000 m^3/day. The water is sourced from the Amu-Bukhara Channel. Treatment is by gravity sand filtration and marginal chlorination.

The Distribution System

2.6 There are no network pumping stations or service reservoirs anywhere in the distribution system. The only potable water storage is in the final water reservoirs at Shokhrud and Zaravshan treatment works. Pressure within the city network is maintained solely by the final water pumpsets at Shokhrud and Zarvashan. There is no standby power generation at the two treatment works but they both have relatively secure main electricity supplies. In the event of power failure the city de-pressurizes quite rapidly.

2.7 Flows and pressures are adjusted by throttling valves and the number of pumps operating. There is no storage between the final water pumpsets at the two treatment works and the city distribution network. The flat topology does not give opportunity to construct a master service reservoir to feed the city.

Control and Monitoring of the System

2.8 None of the system is telemetered. There were no totalizing flowmeters anywhere on the system. Ultrasonic flowmeters on the delivery mains to Shokhrud are non operational and no ability or spares exists to repair them. The level of water in the final water reservoirs at the treatment works is determined by visual inspection. Flow into the city is assessed by the number of final water pumps operating and the nameplate duty of the pumps.

2.9 None of the plant in the treatment works or final water pumping stations operated automatically.

The Installed Pumping Plant

2.10 The majority of the energy for supplying water at Bukhara is used at the raw water pumping station at Ku Mazar and the treatment works at Shrokrud and Zaravshan. All of the pumpsets are horizontal centrifugal units. In total there are 29 centrifugal pumps of which only 24 are operable, 2 are used for filter back-washing and there is 1 wash-water transfer pump. Three of the motors at Ku Mazar are synchronous. The plant is of Russian origin.

2.11 None of the plant is variable speed although final water pumps at two treatment works pump directly into the city network.

2.12 The pumping plant operates at voltages of 6000v and 380v only. The majority of high voltage switchgear used oil interrupters of Russian origin. There was some off-load air-break high-voltage (hv) switchgear. The low-voltage (lv) switchgear was all air-break.

2.13 Details of the pumping plants in the Bukhara are given in Tables 2.1 to 2.3. Usually not all the pumping plant is always available due to failures.

Table 2.1: Ku Mazar Pumping Plant

Location	**Ku Mazar - Built 1978**							
Pumping Station	**Ku Mazar to Shokhrud & Mubarek (Irrigation system)**							
Comment	**to Shokhrud**						**to Mubarek**	
Pump No	1	2	3	4	5	6	7	8
Q (m3/H)	2500	2500	2500	2500	3200	2000	2500	2500
H (m)	62	62	62	62	75	100	45	45
Power (kW)	630	630	630	500	800	800	500	500
Speed (rpm)	1000				1000	1000	750	750
Synchron /Asynchron	Asyn	Syn	Syn	Asyn	Syn	Asyn	Asyn	Asyn
Voltage	6000	6000	6000	6000	6000	6000	6000	6000
Date installed	1984 to 1987 all pumpsets replaced							

Table 2.2: Shokhrud Pumping Plant

Location	**Shokhrud**		**Daily input to city - based on two pumps running 106,800 m3/day**								
Pumping Station	**Intermediate**		**Backwash**		**Shokhrud - Final (to Network)**						
Comment					**Reserve**			**Normal Operation**			
Pump No	1	2	3	4	1	2	3	1	2	3	4
Q (m3/H)	5000	5000	3200	3200	3200	315	315	3200	3200	3200	3200
H (m)	70	70	30	30	75	65	65	75	75	75	75
Power (kW)	400	400	250	250	800	315	315	800	1000	800	800
Speed (rpm)	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Voltage	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000
Date installed	1984 to 1985				1983						

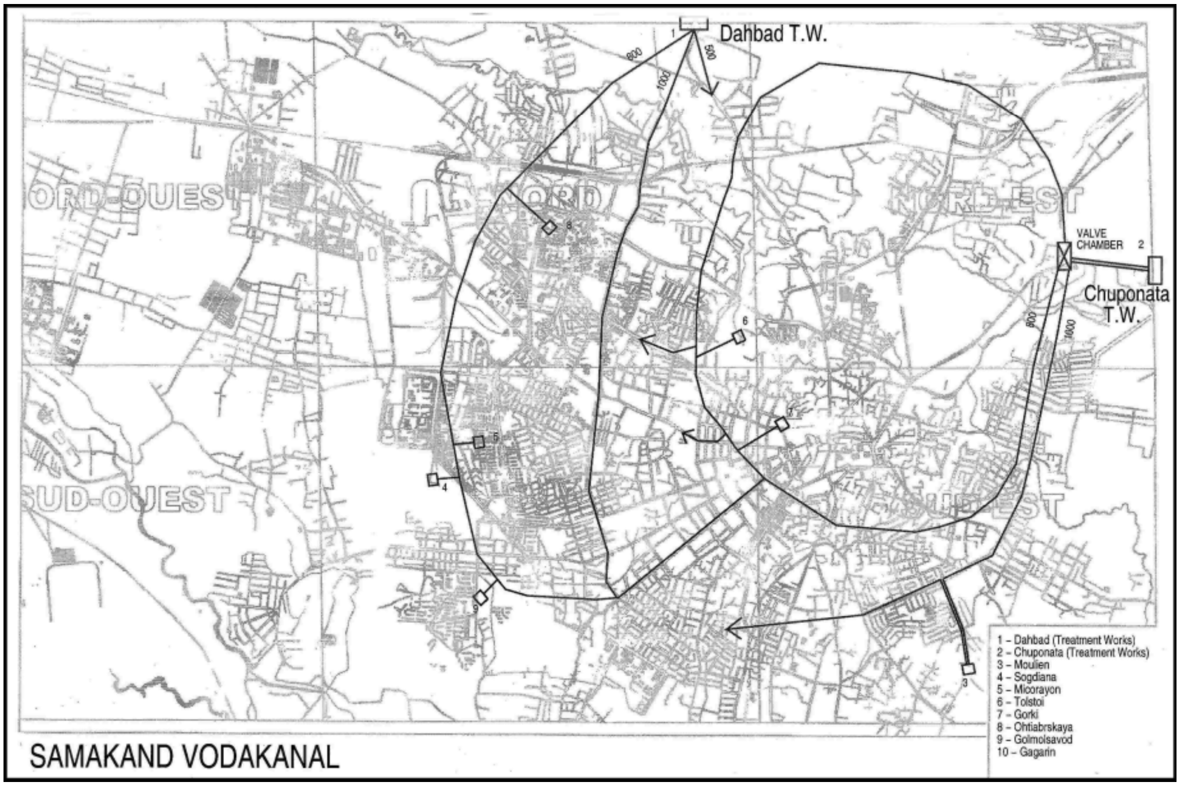
Table 2.3: Shokhrud Pumping Plant

Location	**Zaravshan** **Daily input to city - summer 43,200 m3/day, winter 29,300 m3/day**								
PumpingStation	**Zaravshan - Intake**				**Zaravshan - Final (to Network)**				
Comment	**Normal Operation**		**Reserve**		**Normal Operation**			**Reserve**	
Pump No	1	2	1	2	1	2	3	4	5
Q (m3/H)	1800	1800	1290	1290	1250	1250	1250	900	900
H (m)	30	30	20	20	65	65	65	60	60
Power (kW)	100	125	128	128	315	315	315	200	220
Speed (rpm)	1000	1000	1000	1000	1500	1500	1500	1500	1500
Voltage	380	380	380	380	6000	6000	6000	6000	6000
Date installed	1983				1983				

Samarkand

2.14 Samarkand city has a population in the order of 375,000 people. Water from the wellfields at Dahbed and Chupanata supply water to the city. The three largest of the nine network booster stations in the distribution network were visited in Samarkand. Figure 2.2 shows the key elements of the distribution network in Samarkand.

Figure 2.2: Schematic Layout of Pumping Stations and Reservoirs



Pumping Stations at Water Sources and Main Pumping Stations

2.15 **Dahbed** production facilities have a nominal production capacity of 100,000 m^3/day. The water is currently sourced from 25 wells along the plain of the River Zaravshan. Treatment, actually only disinfection, is marginal chlorination only.

2.16 **Chupanata** production facilities have a nominal production capacity of 200,000 m^3/day. The water currently is sourced from 52 wells along the plain of the River Zaravshan. Treatment is again marginal chlorination only.

The Distribution System

2.17 The final water pumping stations at two treatment works pump about half of the water to service reservoirs of booster pumping stations and the rest directly into the city. The network pumping stations pump directly into the system. There is no gravity fed supplies. Although all of the water into the city is pumped. There are no variable speed drives at either treatment works or pumping stations. Flows and pressures are adjusted by throttling valves and the number or pumps operating. There is no high level storage between the final water pumpsets at the two treatment works and the city distribution network.

2.18 The majority of the network pumping stations only operate between the hours of 5–9 in the morning and 5-9 in the evening. This is because the service reservoirs at each pumping station do not fill quickly enough and have insufficient capacity to sustain the pumps operating to give a 24-hour supply. Without pumping, all floors above ground floor in the apartment blocks will not receive a supply. The intermittent supply creates an abnormal demand profile and probable excessive water usage per capita.

Control and Monitoring of the System

2.19 None of the system is telemetered. Instantaneous flows are measured only on the two mains leaving Chupanata Treatment works and at a distribution chamber dividing flows into the city and to Mouleon Pumping Station. The level of water in the service reservoirs at the pumping stations is only indicated locally by a level probe and light system. Pressures gauges were fitted to some pump deliveries and occasionally to the suction system. Pressure gauges were also fitted to the distribution chamber to one main from Chupanta and to one feed to the centre of the city. Totaliser flowmeters record the flow from each service reservoir and are manually read every day.

2.20 In the central control room, the so called "dispatcher" will ask the operators at pumping stations and treatment works to give him information about the status of pumping plant, reservoir levels, pressures and flows where known. He will instruct the operators to run pumps based on his knowledge of the system. He uses telephone and radio to communicate.

2.21 A simple SCADA system had been installed at Chupanata to give pictorial representation of the new final water pumping station plant. None of the pumping plant anywhere in the treatment works or pumping stations operated automatically.

The installed Pumping Plant

2.22 The largest installed plants at Samarkand are at the wellfields Chuponata & Daghbed. Currently there are 77 operating well pumpsets (32kW each) and 11 final water pumpsets of which seven have an electrical input power of greater than 1MW. The well pumpsets are all submersible pumps and the final water pumpsets are all horizontal centrifugal. There are nine network booster stations within the distribution network in all, with relatively small horizontal centrifugal pumpsets. Three network booster stations were inspected during the inception mission. The pumps are of Russian origin except for the new final water pumpsets at Chupanata, which have ABB motors and Ingersoll Rand pumpsets.

2.23 Two of the six final water pumpsets at Daghbed were originally installed at Chuponata.

2.24 None of the plant is variable speed, although the final water pumps at the two treatment works (Chuponata & Daghbed) pump directly into the city network. The pumping plant operates at voltages of 6000v and 380v only. The majority of high voltage switchgear uses oil interrupters of Russian origin. There is some off-load air break high voltage switchgear. The switchgear for the new plant at Chupanata is vacuum, supplied by GEC Alsthom. The low voltage switchgear is all air break.

2.25 Details of the pumping plants in the Samarkand are given in Tables 2.4 to 2.8.

Table 2.4: Chuponata Pumping Plant

Location	**Chupanata Treatment Works & Pumping Station**								
Pumping Station	**Well Pumpsets**				**Final Water Pumpsets**				
Comment									
Pump No	1	to	52	5 off	1	2	3	4	5
Q (m3/H)	255		255	255	4000	4000	4000	4000	4000
H (m)	40		40	40	95	95	95	95	95
Power (kW)	32		32	32	1335	1335	1335	1335	1250
Speed (rpm)					1000	1000	1000	1000	1000
Voltage	380		380	380	6000	6000	6000	6000	6000
Date of Installation	1985		1985		2000	2000	2000	2000	1985

Table 2.5: Dahbed Pumping Plant

Location	**Dahbed Treatment Works & Pumping Station**								
Pumping Station	**Well Pumpsets**			**Final Water Pumpset**					
Comment	**Operation**		**Reserve**	**Operation**					
Pump No	1 to	25	5 off	1	2	3	4	5	6
Q (m3/H)	255	255	255	4000	1250	1250	4000	1250	1250
H (m)	40	40	40	95	125	125	95	95	125
Power (kW)	32	32	32	1250	630	630	1250	630	630
Speed (rpm)				1000	1000	1000	1000	1000	1000
Voltage	380	380	380	6000	6000	6000	6000	6000	6000
Date of Installation	1984	1984		1985	1985	1985	1985	1985	1985

Table 2.6: Moulien Pumping Plant

Location	**Moulien**		
Pumping Station	**Booster Pumpsets**		
Comment -			
Pump No	1	2	3
Q (m3/H)	3600	3600	3600
H (m)	52	52	52
Power (kW)	630	630	630
Speed (rpm)	730	730	730
Synchron /Asynchron	Synch	Synch	Synch
Voltage	6000	6000	6000
Date of Installation	1989	1989	1989

- Reservoir 1x 10000 m3
- Station operates 5-9 am and 5-9 pm
- Usually only one pump is operated
- Two pumps may be operated when local reservoir is full (to reduce level) or as required by dispatcher
- Only the 1st floor flats (out of 5) get water without pumping
- Delivery Gauge on the delivery main readings passed to dispatcher about 12 times daily

Table 2.7: Sogdiana Pumping station

Location	Sogdiana		
Pumping Station	**Booster Pumpsets**		
Comment	-		
Pump No	1	2	3
Q (m3/H)	400	500	720
H (m)	105	63	70
Power (kW)	132	160	250
Speed (rpm)	1450	1450	1450
Synchron /Asynchron	Async	Async	Async
Voltage	380	380	380
Date of Installation	1980	1988	1992

- Reservoir 3 x 1000 m3
- Station operates 5-9 am and 5-9 pm
- Usually only one pump is operated
- Two pumps may be operated when local reservoir is full (to reduce level) or as required by dispatcher
- Only the 1st floor flats (out of 5) get water without pumping
- All delivery valves are fully open
- Heating Plant (1500m3/hr) is fed from the same main as the service reservoir

Table 2.8: Mircorayon Pumping Plant

Location	Mircorayon					
Pumping Station	**Booster Pumpsets**					
Comment	-					
Pump No	1	2	3	4	5	6
Q (m3/H)	540	400	400	400	540	
H (m)	90	56	105	56	90	
Power (kW)	250	132	160		250	
Speed (rpm)	1470	1470	1450	1000	1470	
Synchron /Asynchron	Async	Async	Async	Async	Async	
Voltage	380	380	380	380	380	
Date of Installation	1986	1986	1975	1986	1986	
Available/Not Available	na		na		na	na

- Reservoir 2 x 2000m3
- Operates 5-9 am and 5-9 pm
- Usually only one pump is operated
- Two pumps may be operated when local reservoir is full (to reduce level) or as required by dispatcher
- Two pumps are ample under all conditions
- Only the 1st floor flats (out of 5) get water without pumping
- All delivery valves are fully open

Standby Plant

2.26 The provision for standby plant in both Buchara and Samarkand Vodakanals is excessive by Western Standards. However, the Vodakanals plant failures are much greater than would be expected in the west, particularly motor failures. An increase in reliability of the plant will enable excessive standby plant to be scrapped. This has a two-fold benefit: the maintenance burden is considerably decreased and the system is simplified further enhancing the reliability.

2.27 The original Russian designs for the pumping stations seemed to provide for about double the standby plant that would be specified in the West. However, some of the pumpsets are now unusable through failure and lack of repair or in some cases have been removed. In most cases the electrical switchgear for the standby plant remains.

2.28 Typically for a Western block level pumping station one duty and one standby pumpset would be installed. For a duty/duty assist pump arrangement as at Chuponata, Dahbed, Shokrud a three or four pump arrangement would be sufficient. This would be designed to allow one pump failure at full site output. The precise number of pumps would be dependant on the pressure/flow range to be efficiently accommodated.

3

Condition of the Works

Causes of Poor Energy Efficiency

3.1 The Buckahara and Smarkand Vodakanals pumped water distribution systems efficiency is compromised, in order of severity, by:

- Leakage from the pumped system.
- Condition of the pumping plant.
- Correct sizing and application of the pumping plant.
- Design of the distribution system.
- Operation of the pumping plant and distribution system.

3.2 The magnitude of each can only be estimated, but from this and other studies it is reasonable to deduce that attention to leakage and the condition of the pumping plant will give the greatest efficiency improvement. Detail on the condition of the pumping plant and appropriateness of the sizing is given in Chapter 4.

3.3 The design of the distribution system from pump to customer's tap is critical in setting levels of service (e.g. pressure at the customer's tap, reliability of supply) and the amount of energy needed to drive the water through the distribution system. Efficiency decreases as the pressure that is lost through friction in the distribution pipes increases. The friction loss is determined by the flow and the size of the pipe. An efficient distribution system will require a lower pressure from the pumps (and thus less energy) to drive a flow of water to the customer than a less efficient one. The detail of improvements required to the distribution system and the effect on pressure required at the pump input requires a detailed network study. There is clearly a linkage in this respect between water loss management and energy efficiency. Reduced distribution pressures reduce water losses, but whether reduced distribution pressures reduce energy is determined by the system configuration. Where it is possible to reduce distribution pressures by modifying the delivery pressure from the pumping station, this will also reduce energy usage unless this is achieved by throttling the pumps, however if distribution pressure reduction is achieved through the installation of pressure reducing valves, there will be no energy saving.

3.4 In the Bukhara and Samarkand Vodakanals it is likely that modifications and repairs to the distribution system including better pressure management, will largely result in a higher level of service to the customer (i.e. a water supply reliably maintained at the correct pressure) without a change to the specification of the final pumps at the treatment works. In Samarkand it is expected that a reliable supply will stop the prevalent customer habit of needlessly storing excessive amounts of water and then wasting it. In both Vodakanals, repairs to the distribution system and reducing leakage will however reduce the amount of water that needs to be pumped and thus enable less pumping plant to be used to keep the system pressurized at times of low demand during the day. This will result in substantial energy saving.

3.5 Some energy is wasted in the Vodakanals by throttling of pumps, operation of poorly matched pumpsets feeding into the same system and lost pressure in the distribution system by inappropriate valve operation. The instances of pump delivery valve throttling recorded were to prevent motor overload rather than to control the supply of water to distribution. The correct sizing of pumps and matching of new motors would remove the need for throttling. It is likely that this situation came about due to the replacement of a failed motor with the nearest alternative rating available at the time – rather than the Russian designer mismatching the pair; the general tendency was to oversize. Notably, however, it is necessary to throttle the new Final Water Pumps at Chupanata - not because the pumps are poorly matched to the system but because the motors are undersized for the pumpsets. The motors could be replaced at considerable expense but this is not a practical option. Alternatively the pump impellers could be trimmed and the pump duty changed slightly. This would require dismantling the four pumps in a planned program and shipping the rotors to an Ingersoll Dresser workshop. Whilst there is occurrence of mismatched pumps operating together, this again resulted in comparatively small wasted energy. Further details are given in Chapter 4.

3.6 A large electricity supply distribution system will lose energy through heat in the cables, switchgear and transformers. The treatment works and booster pumping stations are large users of electricity and do have cables, switchgear and transformers from which energy could be lost. Whilst the condition of the electrical equipment was poor, there was no evidence to indicate lost efficiency as a result. As with the pumping plant, the electrical cabling was generously sized. There was no sign of heat damage to cables or switchgear. Cables under full load were only slightly warm to the touch. All transformers have resistance and iron losses. Distribution transformer efficiency is normally in the order of 98% at full load and will not deteriorate significantly with age. The oil will however need to be tested regularly and changed as necessary. The condition of the electrical equipment at the Vodakanals is more relevant to the reliability and sustainability of the system – it is an asset condition/replacement issue. Presently the electrical assets are “being sweated” to financial advantage with no major effect on operating costs. This of course is not sustainable but asset renewal could be deferred for a little longer.

3.7 The poor condition of the pumping plant is largely not due to maintenance practices. There are only certain things that an operator-maintainer can do to the pump. Essentially these are: replace the bearings, replace the gaskets and seals, replace wearing rings, and adjust the glands. The condition of pump impellors, the clearances within the pumps and the condition of the surfaces within the pump have a major effect on efficiency. Whilst it is recognized in the Vodakanals that the alignment of pumps to motors is important to avoid premature bearing failure, the Consultant does believe that improvement might be possible – this does require the appropriate equipment and training. This does not however affect energy efficiency.

3.8 Poor rewinding of the pump motors will result in poor efficiency typically in the order of 3% less than a motor in good condition. A large high voltage electric motor in good condition at full load will have efficiency above 95%. The energy lost through motor inefficiency is in addition to the losses due to pump inefficiency. There is no correlation between the efficiency of a pump and its driving motor; they are separate quantities but together give the efficiency of the pumpset (i.e. motor and pump together). The Vodakanal's motor failure rate is extremely high. A high quality rewind should last ten years. Some Vodakanal rewinds are lasting about a year before failure. Specialists must undertake rewinding of motors. Correctly, the Vodakanal's outsource this work, but the quality of repair that they can afford is very poor. This is a money issue, not a reflection on the competence of the Vodakanal staff.

3.9 The poor efficiency of the large horizontal, close coupled, centrifugal pumps at the treatment works and in the block level booster pumping stations is due to:

- Mismatching to system.
- Worn out impellors (see picture).
- Worn clearances.
- Poor quality of pump internal services resulting in excessive friction.

3.10 Site maintenance staff cannot rectify these matters. Pumps should be refurbished at a specialist workshop, preferably by the original pump supplier who may have the patterns for the original impellors. Quotations should always be sort in advance - in some cases it may be better value to replace the complete pumpset with a new one.

3.11 The borehole pumps in Samarkand are simply worn-out and should have been replaced sometime ago. It is suspected that the deterioration of these pumps is accelerated by the sand content of the raw water.

Bukhara

Condition of the Mechanical and Electrical plant

3.12 The split casing centrifugal pumps were generally in a satisfactory visual condition.

3.13 It is understood that the motors are frequently rewound, sometimes once a year or more. This is a major cause of operating difficulties and an expense. The frequent rewinding of the motors will have had a detrimental effect on the laminations therefore decreasing efficiency. The frequency of repair is excessive and suggests a very poor quality of repair. In the long term it would be cheaper to procure a high quality motors rewinds which should last ten years.

3.14 The electric power cables are not believed to be unreliable. They appear to be paper insulated without armoring. They have not been electrically insulation tested. At Ku Mazar particularly and generally at other sites they are very poorly installed. From visual inspection the general condition of the cables appears to be poor.

3.15 The physical condition of the LV Switchgear was poor but apparently reliable. Protection against electric shock by Western Standards was extremely poor. Cabinet doors are usually left open, parts are missing and the equipment is in a filthy state.

Figure 3.1: Condition of impeller

Figure 3.2: Cables support and protection

Condition of the Buildings

3.16 The buildings are probably structural sound. Roof leaks are ubiquitous and most pump floors require a new concrete screed. New doors and windows are required. An improved means of draining down pumps is required to prevent the pump floor from frequently becoming very wet and damaging the finish. Pumpset plinths etc may require minor remedial works. All of this work could be done by local labour at a competitive cost.

Housekeeping and Maintenance

3.17 The visible condition of the treatment works and pumping stations at all sites visited was poor. The lack of building maintenance contributed greatly to the overall impression of neglect. There is also a lack of suitable skills and training. Local assistance is required with the maintenance of the synchronous motors at Ku Mazar. Generally maintenance is limited to breakdown repair. It is possible that whilst the general apparent condition of the majority of the plant is very poor, the actual operating efficiency may be satisfactory.

3.18 The pumpsets are stripped every three months. The bearings are greased. There is little evidence of maintenance manuals or circuit diagrams.

3.19 The problem would seem to be lack of money for spares and general maintenance. It was therefore essential to test the operating efficiency of the plant to determine the true condition.

Samarkand

Condition of the Mechanical and Electrical plant

3.20 The visible condition of the treatment works and pumping stations at all sites visited was extremely poor. The condition of the electrical power cabling at most sites was extremely poor. They appear to be paper insulated without armoring. They have not been electrically insulation tested. They are very poorly installed on cable trays or otherwise. The hv and lv switchgear at most sites appeared to be poorly maintained but apparently were reliable. Protection against electric shock by Western Standards was extremely poor. Cabinet doors are usually left open, parts are missing and the equipment is in a filthy state. The lack of building maintenance contributed greatly to the overall impression of neglect.

3.21 The new final water pumps and switchgear at Chupanata and plant at Meuleon network pumping stations were in good condition. The latter is particularly notable since it is not new plant but had clearly been well cared for. At Micorayon network pumping station, only three of the originally six pumpsets could be operated. Motors had burnt out on the other three and had not been repaired. There were similar situations at other sites.

3.22 The well pumpsets, although not visually examined, are believed to be in poor physical condition. Final split casing centrifugal pumps were generally in a satisfactory condition.

3.23 It is understood that the motors are frequently rewound – sometimes once a year or more. This is a major cause of operating difficulties and an expense. The frequent rewinding of the motors will have had a detrimental effect on the laminations therefore decreasing efficiency. The frequency of repair is excessive and suggests a very poor quality of repair.

Figure 3.3: Workshop at Pumping Station

Figure 3.4: Cables support and protection

Condition of the Buildings

3.24 The Dahbed Treatment Works building is probably structural sound. The roof leaks and the metal gallery floor require replacement or refitting. The pump floor requires a new concrete screed. New doors and windows required. Steps to plant floor should be replaced with a safer full tread type. Present steps are manufactured from reinforcing rod and often the steps are treacherous. General decoration is needed throughout. An improved means of draining down pumps is required to prevent the pump floor from frequently becoming very wet and damaging the finish. Pumpset plinths etc may require minor remedial works. All of this work could be done by local labour at a competitive cost.

Housekeeping and Maintenance

3.25 At Dahbed grease had been applied everywhere inside building apparently to stop floors and other metalwork rusting because roof is leaking. This makes the working conditions unpleasant, dirty and dangerous. A general lack of care is perceived. The maintenance staff did not have even the most basic of tools. This made repairs either impossible or of a very low standard. The problem would seem to be lack of money for spares and general maintenance. There is also a lack of suitable skills and training. Generally maintenance is limited to breakdown repair. It is possible that whilst the general apparent condition of the majority of the plant is very poor, the actual operating efficiency may be satisfactory. It was therefore essential to test the operating efficiency of the plant to determine the true condition.

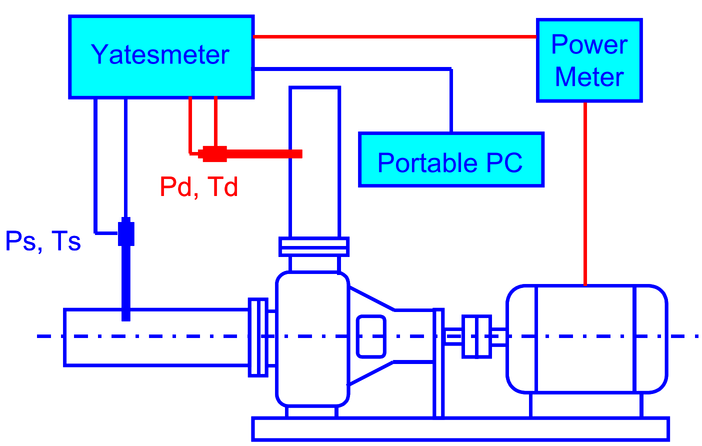
4

Pump Efficiency Tests

Pump Testing Methodology

4.1 A thermodynamic method of determining pump efficiencies was employed using the Yatesmeter equipment. This is a very accurate method, which does not require a flow meter but does require specialist equipment. It is not sensitive to pipework configurations. The thermodynamic method is based on the theory that any energy that is supplied to the pumpset, which is not converted into pumping head, is lost in heat, which increases the temperature of the water pumped. It is this increase in water temperature that is used to determine the efficiency of the pumpset. Figure 4.1 illustrates the theoretical basis of the thermodynamic tests.

Figure 4.1: The Theoretical Basis of Thermodynamic Pump Testing



$$\text{Efficiency} = \frac{\text{work out}}{\text{work in}}$$

$$\text{work in} = \text{work out} + \text{losses}$$

$$\text{work out} = \rho g Q H$$

$$\text{losses} = \rho Q C_p \Delta T$$

$$\boxed{\text{Efficiency} = \frac{1}{1 + \dfrac{C_p \Delta T}{gH}}}$$

C_p = specific heat at constant pressure (J/kg.K)

ρ = density of fluid (kg/m^3)

g = gravitational constant (9.81 m/s)

Q = volumetric flow rate (m^3/s)

P_s = suction pressure

P_d = delivery pressure

T_s = water temperature (suction)

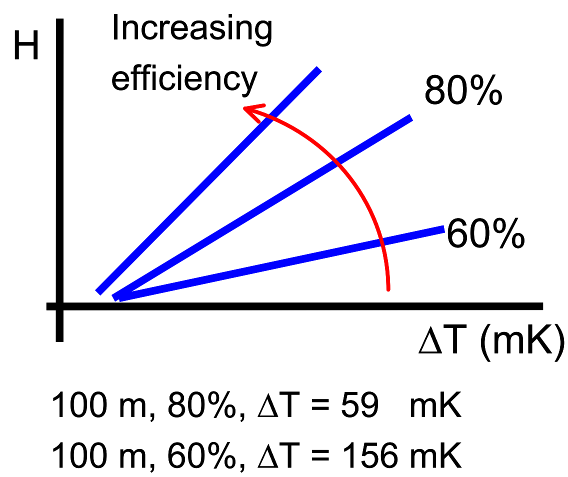
T_d = water temperature (delivery)

$H = P_d – P_s$

$\Delta T = T_d - T_s$

4.2 The greater the increase in temperature recorded by the test, the lower the efficiency of the pump, as illustrated in Figure 4.2.

Figure 4.2: Relationship between Temperature Changes and Efficiency



4.3 The conventional method of testing pump efficiency is to measure the suction and delivery pressures, flow and power consumed. The advantages of the thermodynamic method over the conventional testing method are:

- It does not rely on existing, installed flow metering equipment, which is often not installed and even if installed, the accuracy of the metering is unknown.
- Pump efficiency and performance can be accurately determined on-site.
- Accuracy is not sensitive to pipework configuration.
- The equipment is easily installed, with minimal installation work required.
- Test work can be carried out with the minimum disruption to operations.

4.4 The results of the thermodynamic test method can be used for a variety of different purposes including to:

- Determine pump efficiency.
- Detect loss of performance and optimize maintenance intervals.

- Assess the effectiveness of refurbishment work.
- Optimize operating schedules to minimize operating costs.
- Evaluate system losses and condition.
- Assess fitness for purpose of the pumpset.
- Calibrate permanently installed flowmeters.
- Provide a basis for risk reward contracting.

4.5 The suction and delivery water pressures and temperatures are measured using highly sensitive sensors. The power into the motor is also measured using a clamp-on power meter. From all of this information it is possible to determine the pump efficiency, flow, head and motor input power. To determine the pump curves the delivery valve is incrementally throttled and measurements taken at each position. The results also enabled system curves to be derived.

4.6 The Yatesmeter requires access to the suction and discharge of the pump under test. For a dry well configuration, two ½ inch BSP tappings are required, one in the suction of the pump and one in the discharge of the pump. The tappings are installed 2 pipe diameters away from the flanges of the pump. The accuracy of the method is not sensitive to pipework configurations on the suction and delivery sides of the pump. Figure 4.3 details the standard arrangement used for a Yatesmeter tapping, Figure 4.4 shows the location of the tappings on a typical split casing centrifugal pump-set and Figure 4.5 illustrates the configuration of a typical Yatesmeter pump testing installation.

Figure 4.3: Standard Tapping Arrangement

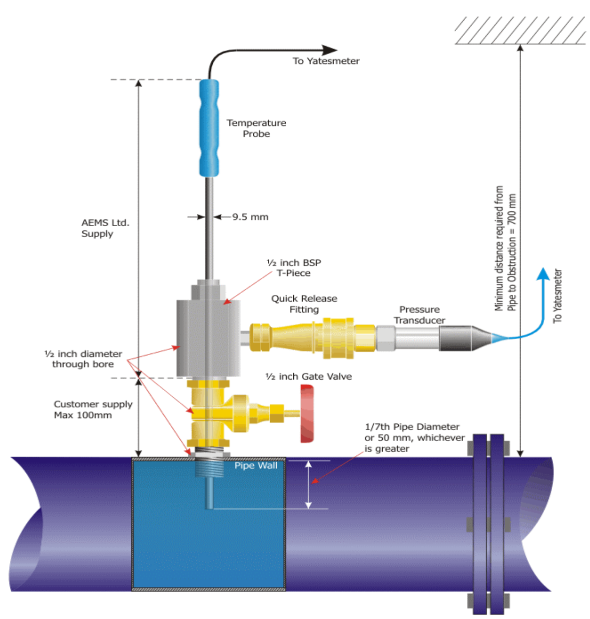


Figure 4.4: Split Case Tapping Arrangement

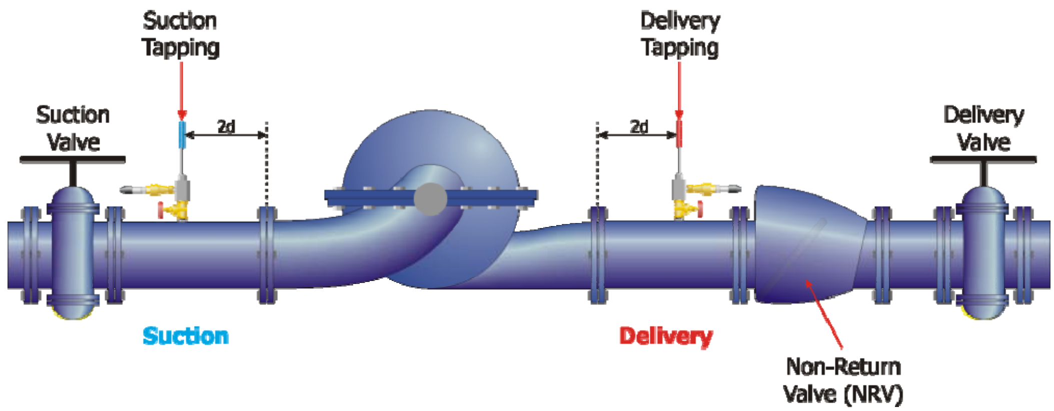
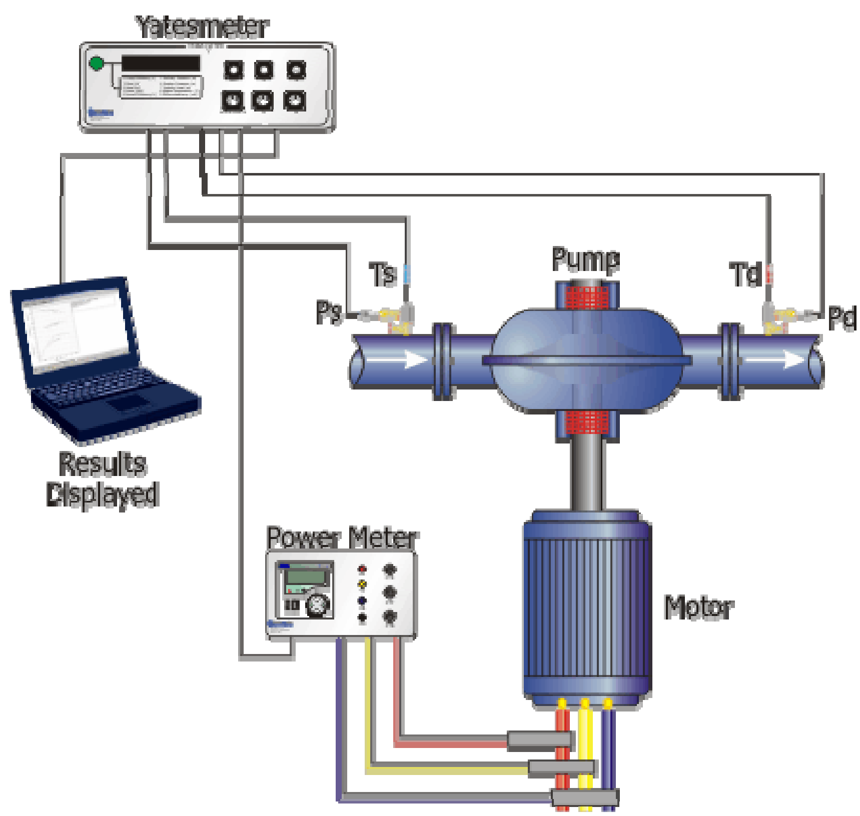


Figure 4.5: Typical Yatesmeter Pump Test Installation



4.7 For each of the pumps tested in Bukhara and Samarkand it was necessary to install tapping points at the required locations on the suction and delivery pipework. Figure 4.6 shows a tapping being welded to the suction pipework of one of the pump sets and Figure 4.7 shows a test in progress on one of the well pumpsets.

Figure 4.6: Welding of tappings on suction pipe

Figure 4.7: Testing on a well pumpset

4.8 Although the tests undertaken in Bukhara and Samarkand obtained all the data required to determine the efficiency of each pump set tested, only limited data was collected for a full set of system curves because of the lack of appropriate flow metering on the delivery mains from the pumping stations. The data obtained however contributed to the pump test results in determining the optimum duties for refurbished or new pumps.

Efficiency Shortfalls

4.9 The following tables show a summary of the most pertinent aspects of the operating characteristics of each of the pumps tested.

4.10 The **Operating Point** table gives the normal conditions of the pump as advised by the Vodokanal. The figures given in brackets under Pump Head and Pump Flow are the duty points of the pumps also advised by the Vodokanal. It is recognized that the duty point given by the Vodakanals may not be completely accurate, but this data is included to provide background information only. This data is not used in determining the present efficiency of the pump or in the formulae for determining the Optimum or Expected Efficiency. The Best Efficiency Point used in the calculations was determined by test alone.

4.11 The **Best Efficiency Point** data was determined by adjusting the operating conditions of the pump as part of the test procedure.

4.12 The **Best Efficiency Point – Comparison and Shortfall** table includes the best present efficiency for the pump and the best available efficiency for each pump. This is calculated using the **Anderson relationship**, determined through empirical data, as follows:

Optimum Efficiency = 100*(0.94-(q/0.075768)^-0.32) %

And

Expected Efficiency = Optimum Efficiency - 5%

where q is the flow rate achieved at the pump’s best efficiency point (BEP) in l/s.

4.13 The manufacturer’s data for the pumps was unavailable. An assessment has been made of the efficiencies that could be achieved through refurbishment. The optimum efficiency corresponds to the expected best efficiency performance of a Western European pump. The expected efficiency given corresponds to that which would be available through Eastern European suppliers.

4.14 The shortfall from expected efficiency is calculated as follows:

100 x (BEP Efficiency – Expected Efficiency)/Expected Efficiency

4.15 For each pumping station comments are made where relevant as to possible actions that might be appropriate in the way of refurbishment, replacement and other remedial processes.

4.16 During the testing, the motor efficiencies were calculated using an algorithm based on western European type motors. It was understood that a number of the motors encountered had been rewound at some time at least once. This will have an obvious effect on the shaft power to the pump. Also in the thermodynamic calculations, the power is directly proportional to the flow rate the pump produces.

Any results for pumps with rewound motors should be considered with the appropriately reduced motor efficiency and reduce the flow accordingly.

4.17 Note: Figures in Brackets ( ) mean in all tables data provided by the Vodokanals and are included for comparative purposes.

Bukhara

Summary of Results

4.18 Most of the Bukhara pumpsets are incorrectly sized for duty resulting in poor efficiency and in some cases overload of the motors. Many of the pumps could probably be refurbished and adjusted by a pump manufacturer to better meet duty and improve efficiency but others are best replaced.

Table 4.1: Overview Efficiency Tests Bukhara

Station Name	Pump No	Duty Point		Current Normal Operating Point:				Current Best Efficiency Point:		As-New Pump Efficiency:		Shortfall From Expected Efficiency
		Head (m)	Flow (m3/h)	Head (m)	Input Power (kW)	Pump Eff'y (%)	Flow (m3/h)	BEP Flow (m3/h)	BEP Eff'y (%)	Optimal	Expected (-5%)	
Source of Data		Vodokanal	Vodokanal	Measured	Measured	Computed	Computed	Determined from tests	Determined from tests	Computed	Computed	Computed
Kuymazar Final	2	62	2500	33	459.6	55.6	2748	2122	72.9	88.3	83.3	-12.5
Kuymazar Final	3	62	2500	34.4	518.8	52.9	2833	2020	80.2	88.3	83.3	-3.7
Kuymazar Final	5	75	3200	60.4	742	65.5	2871	2454	71	88.3	83.3	-14.8
Kuymazar Final	6	100	2000	100.9	868.7	60.2	1860	2259	63.5	88.3	83.3	-23.8
Zaravshan Final	6	65	1000	56.4	331.6	68.6	1401.8	1126.8	72.9	87.0	82.0	-11.1
Zaravshan Final	3	65	500	46.9	204.1	37.4	558.3	422.0	48.6	84.4	79.4	-38.8
Zaravshan Intake	1	30	1800	11.3	86.2	61.3	1605.8	1458.5	66.2	87.7	82.7	-20.0
Zaravshan Intake	2	30	1800	13.5	99.7	70.5	1787.5	1565.9	73.1	87.7	82.7	-11.6
Shohrud Intermediate	2	30	5000	15.3	508	69.7	8069	9209	71.4	90.5	85.5	-16.5
Shohrud Final	1	75	3200	71.5	813.4	66.6	2701.2	3161	67.6	88.9	83.9	-19.4
Shohrud Reserve	2	65	1500	20.3	322.4	35.7	1981.7	1410	76.2	88.9	83.9	-9.2

Shohrud Final	3	65	1500	28.2	306.7	42.1	1599.6	975.6	63.3	88.9	83.9	-24.6
Shohrud Final	5	75	3200	48.1	843.2	57.4	3609	3329	61.3	89	84	-27.0
Shohrud Final	7	75	3200	39.8	703.9	65.3	4116	2849	75.9	88.9	83.9	-9.5

Pump condition and potential for refurbishment:

satisfactory	fair	poor

Shokhrud Intermediate Pumps

4.19 The efficiency of Intermediate Pump 2 at Normal Operating Point is in the order of 70%. This is reasonable efficiency. The pump could probably be **refurbished** to give efficiency in excess of 80%. The pump duty point has too high head for it to operate at its most efficient – a duty point head in the order of 12 m would be appropriate. Fixed speed pumps as installed are most suited to the duty since the process flow through the works is relatively constant and the static head is a large component of the total head.

Table 4.2: Bukhara - Shokrud Intermediate Pumps –Operating Point

Operating Point

Pump No.	Pump Head (m)	Power to Motor (kW)	Pump Efficiency (%)	Pump Flow (m3/hr)
2	15.3 (30)	508	**69.7**	8,069 (5,000)

Table 4.3: Bukhara - Shokrud Intermediate Pumps BEP

Best Efficiency Point (BEP)

Pump No.	Pump Head (m)	Power to Motor (kW)	Pump Efficiency (%)	Pump Flow (m^3/h)
2	14.2	530	71.3	9209

Table 4.4: Bukhara - Shokrud Intermediate Pumps BEP – Comparison & Shortfall

Best Efficiency Point – Comparison and Shortfall

Pump No.	Current Flow m3/hr	Current Efficiency %	Anderson Efficiency %	Expected Efficiency %	% Shortfall to Expected Efficiency
2	9,209	71.3	90.5	**85.5**	-16.5

Shokhrud Final Pumps

4.20 The efficiencies of all of the Final Pumps at Normal Operating Point are poor. There are two sizes of pumps and the higher output units run throttled under normal operating conditions. Overload of the motors in excess of 10% occurs under certain conditions.

4.21 Pumps 2 and 7 could be refurbished but considerable adjustment to duty point would be required.

4.22 Variable speed pumpsets are normally appropriate for pumping into a closed distribution system but are impractical in larger sizes – a multiple pump arrangement is probably the most suitable. These two pumps could be suitable for refurbishment and trimming to the correct duty.

Table 4.5: Bukhara - Shokhrud Final Pumps – Operating Point

Operating Point

Pump No.	Pump Head (m)	Power to Motor (kW)	Pump Efficiency (%)	Pump Flow (m3/hr)
1	71.5 (75)	813.4	66.6	2,701 (3,200)
2	20.3 (65)	322.4	35.7	1,982 (1,500)
3	28.2 (65)	306.7	42.1	1,600 (1,500)
5	48.1 (75)	843.2	57.4	3,609 (3,200)
7	39.8 (75)	703.9	65.3	4,116 (3,200)

Table 4.6: Bukhara - Shokhrud Final Pumps – BEP

Best Efficiency Point (BEP)

Pump No.	Pump Head (m)	Power to Motor (kW)	Pump Efficiency (%)	Pump Flow (m^3/h)
1	66.5	853.4	69.4	3,161
2	61.2	327.6	76.2	1,410
3	64.5	286.1	63.0	976
5	56.0	829.0	61.3	3,239
7	57.4	606.5	75.8	2,849

Table 4.7: Bukhara - Shokhrud Final Pumps – BEP – Comparison & Shortfall

Best Efficiency Point – Comparison and Shortfall

Pump No.	Current Flow m3/hr	Current Efficiency %	Anderson Efficiency %	Expected Efficiency %	% Shortfall to Expected Efficiency
1	3,161	69.4	88.9	83.9	-19.4
2	1,410	76.2	88.9	83.9	-9.18
3	976	63.0	88.9	83.9	-24.6
5	3,329	61.3	89.0	84.0	-17.28
7	2,849	75.8	88.9	83.9	-9.5

Ku Mazar Final

4.23 The four pumps tested at Ku Mazar are operating at relatively poor efficiencies due to mismatching to the system. All four pumps could be refurbished and be equipped with impellers more suitable for the duty. Fixed speed pumps are appropriate.

Table 4.8: Bukhara – Ku Mazar Final Pumps – Operating Point

Operating Point

Pump No.	Pump Head (m)	Power to Motor (kW)	Pump Efficiency (%)	Pump Flow (m3/hr)
2	33.0 (62)	459.6	55.6	2,748 (2,500)
3	34.4 (62)	518.8	52.9	2,833 (2,500)
5	60.4 (75)	742.0	65.5	2,871 (3,200)
6	100.9 (100)	868.7	60.2	1,860 (2,000)

Table 4.9: Bukhara – Ku Mazar Final Pumps – BEP

Best Efficiency Point

Pump No.	Pump Head (m)	Power to Motor (kW)	Pump Efficiency (%)	Pump Flow (m^3/h)
2	56.2	459.9	72.9	2,122
3	71.2	50.6	80.2	2,020
5	72.1	698.6	71.0	2,454
6	94.6	939.0	63.5	2,259

Table 4.10: Bukhara – Ku Mazar Final Pumps – BEP – Comparison & Shortfall

Best Efficiency Point – Comparison and Shortfall

Pump No.	Current Flow m3/hr	Current Efficiency %	Anderson Efficiency %	Expected Efficiency %	% Shortfall to Expected Efficiency
2	2,122	72.9	88.3	83.3	-12.48
3	2,020	80.2	88.3	83.3	-3.72
5	2,454	71.0	88.3	83.3	-14.77
6	2,259	63.5	88.3	83.3	-23.77

Zaravshan Final

4.24 Pump No.3 is in very poor condition and not matched to the system, giving an efficiency of nearly 37% under normal operating conditions with a maximum efficiency obtained of 47%. Pump No.6 is in relatively good condition giving an efficiency of nearly 69% under normal operating conditions. The pump is not correctly matched to duty - as this is approached under test conditions the efficiency rises to 73%. This pump could be refurbished.

4.25 The final pumps deliver directly into the distribution system which has a low static but high dynamic head. The appropriate solution to constantly maintain the desired system pressure with the most efficient use of energy is with variable speed pumpsets. Alternatively multiple similar fixed speed pumpsets could be used.

Table 4.11: Bukhara – Zaravshan Final Pumps – Operating Point

Operating Point

Pump No.	Pump Head (m)	Power to Motor (kW)	Pump Efficiency (%)	Pump Flow (m3/hr)
3	46.9 (65)	204.1	37.4	558.3 (1000)
6	56.4 (65)	331.6	68.6	1401.8 (500)

Table 4.12: Bukhara - Zaravshan Final Pumps – BEP

Best Efficiency Point

Pump No.	Pump Head (m)	Power to Motor (kW)	Pump Efficiency (%)	Pump Flow (m^3/h)
3	76.8	194.7	48.6	422.0
6	66.2	294.7	72.9	1126.8

Table 4.13: Bukhara – Zaravshan Final Pumps – BEP – Comparison & Shortfall

Best Efficiency Point – Comparison and Shortfall

Pump No.	Current Flow m3/hr	Current Efficiency %	Anderson Efficiency %	Expected Efficiency %	% Shortfall to Expected Efficiency
3	422.0	48.6	84.4	79.4	38.79
6	1126.8	72.9	87.0	82.0	11.10

Zaravshan Intake

4.26 Intake pump 1 at normal operating point presently gives efficiency in the order of 61% and could probably be refurbished. Intake pump 2 at normal operating point presently gives a relatively good efficiency in the order of 71% and is likely to be suitable for refurbishment to 80% or more efficiency. Both intake pumps are not sized correctly for duty (too high head) resulting in a less than optimum efficiency and excessive energy consumption.

Table 4.14: Bukhara – Zaravshan Intake Pumps – Operating Point

Operating Point

Pump No.	Pump Head (m)	Power to Motor (kW)	Pump Efficiency (%)	Pump Flow (m3/hr)
1	11.3 (30)	86.2	61.3	1605.8 (1800)
2	13.5 (30)	99.7	70.5	1787.5 (1800)

Table 4.15: Bukhara - Zaravshan Intake Pumps – BEP

Best Efficiency Point

Pump No.	Pump Head (m)	Power to Motor (kW)	Pump Efficiency (%)	Pump Flow (m^3/h)
1	13.7	87.9	66.1	1458.5
2	16.1	100.5	72.9	1565.9

Table 4.16: Bukhara – Zaravshan Intake Pumps – BEP – Comparison & Shortfall

Best Efficiency Point – Comparison and Shortfall

Pump No.	Current Flow m3/hr	Current Efficiency %	Anderson Efficiency %	Expected Efficiency %	% Shortfall to Expected Efficiency
1	1458.5	66.1	87.7	82.5	19.88
2	1565.9	72.9	87.7	82.5	11.64

Samarkand

Summary of Results

4.28 A total of six well pumpsets were tested at the two treatment works in Samarkand. They are by far the most inefficient of all pumping plant tested in Samarkand, having an average efficiency of slightly less than 40%. The remaining plant in Samarkand had an average efficiency of 66%. Whilst the Samarkand Booster Pumping Stations are generally in a very poor condition (excepting Mouleon) the efficiency of the pumps is tolerable - appearances are not representative of performance. The new final water pumps at Chuponata have excellent performance; however all of the motors are undersized. This would result in overload of the motors if the pumpsets were left unthrottled.

Table 4.17: Overview Efficiency Tests Samarkand

Station Name	Pump	Duty Point		Current Normal Operating Point:				Current Best Efficiency Point:		As-New Pump Efficiency:		Shortfall from Expected Efficiency
		Head (m)	Flow (m3/h)	Head (m)	Input Power (kW)	Pump Eff'y (%)	Flow (m3/h)	BEP Flow (m3/h)	BEP Eff'y (%)	Optimal	Expected	
Source of Data		Vodokanal	Vodokanal	Measured	Measured	Computed	Computed	Determined from tests	Determined from tests	Computed	Computed	Computed
Chupanata Well Field	14	30	255	15.7	35.7	37.4	257.3	257.3	41	68	63	-34.9
Chupanata Well Field	15	30	255	14.3	36.7	25.7	185.4	185.4	29.5	68	63	-53.2
Chupanata Well Field	17	30	255	10.7	26.9	29.1	195.1	195.1	41.2	68	63	-34.6
Chupanata Final PS	1	95	4000	85.1	1301.4	83.5	4574.6	4282.9	83.9	89.5	84.5	-0.7
Dahbed Well Field	1	30	255	25.2	29.8	44.8	194.4	194.4	44.8	68	63	-28.9

Dahbed Well Field	2	30	255	25	37.6	44.8	260.6	128	50	68	63	-20.6
Dahbed Well Field	4	30	255	23.9	31.2	47.3	148.7	148.7	31	68	63	-50.8
Dahbed Final	2	125	1250	106.4	649.2	71.5	1535.6	1353.7	72.9	87.5	82.5	-11.6
Dahbed Final	3	125	1250	116.1	613.2	64	1189.3	1093.9	65.2	87.5	82.5	-21.0
Dahbed Final	5	95	4000	134.2	604.8	69.5	1102.1	1322.8	72.9	87.5	82.5	-11.6
Dahbed Final	6	125	1250	104.7	714.7	67.9	1630.6	1386.6	71	87.5	82.5	-13.9
Moulien	2	55	3200	49.0	381.5	77.2	2128.1	1955.3	78	88.2	83.2	-6.3
Moulien	4	55	3200	36.9	382.7	56.8	2089.4	1790.2	73.4	88.0	83.0	-11.6
Sogdiana Booster	2	63	500	63	128.9	66.5	466.7	424.4	67.1	84.5	79.5	-15.6
Sogdiana Booster	3	70	720	69.4	139.5	67.4	465.4	420.2	68	84.5	79.5	-14.5
Micorayon Booster	3			56.1	83.5	54	272	184.8	63.7	82.1	77.1	-17.4
Micorayon Booster	5			51.4	291.7	51.7	1016.1	812.2	66.3	86.3	81.3	-18.5

Pump condition and potential for refurbishment:

satisfactory	fair	poor

Chupanata Well Field

4.29 The sample of three well pumpsets tested had a very poor performance - all in the order of 40%. A new performance for pumps of this type is in the order of 63% or better. The well pumpsets had slightly too high head and were not optimally matched to duty. All of the well pumpsets are of similar type and age, have had similar maintenance and are subject to similar duties and water; it may therefore be assumed that they all have a similar efficiency. The pumps are beyond refurbishment and should urgently be replaced with new.

Table 4.18: Samarkand – Chupanata Well Field Pumps – Operating Point

Operating Point

Pump No.	Pump Head (m)	Power to Motor (kW)	Overall Efficiency (%)	Pump Flow (m3/hr)
14	15.7 (30)	35.7	37.4	313.2 (255)
15	14.3 (30)	36.7	25.7	241.9 (255)
17	10.7 (30)	26.9	29.1	268.9 (255)

Table 4.19: Samarkand – Chupanata Well Field Pumps – BEP

Best Efficiency Point

Pump No.	Pump Head (m)	Power to Motor (kW)	Overall Efficiency (%)	Pump Flow (m^3/h)
14	20.6	35.1	41.2	257.3
15	21.1	35.6	29.9	185.4
17	20.8	26.7	41.4	195.1

Table 4.20: Samarkand – Chupanata Well Field Pumps – BEP – Comparison & Shortfall

Best Efficiency Point – Comparison and Shortfall

Pump No.	Current Flow m3/hr	Current Efficiency %	Anderson Efficiency %	Expected Efficiency %	% Shortfall to Expected Efficiency
14	257.3	41.2	68.0	63.0	-34.9
15	185.4	29.9	68.0	63.0	-53.2
17	195.1	41.4	68.0	63.0	-34.6

Dahbed Well Field

4.30 The sample of three well pumpsets tested had a very poor performance - all in the order of 40%. A new performance for pumps of this type is in the order of 63% or better. The well pumpsets had slightly too high head and were not optimally matched to duty. All of the well pumpsets are of similar type and age, have had similar maintenance and are subject to similar duties and water; it may therefore be assumed that they all have a similar efficiency. The pumps are beyond refurbishment and should urgently be replaced with new.

Table 4.21: Samarkand – Dahbed Well Field Pumps – Operating Point

Operating Point

Pump No.	Pump Head (m)	Power to Motor (kW)	Overall Efficiency (%)	Pump Flow (m3/hr)
1	25.2 (30)	29.8	44.8	194.4 (255)
2	25.0 (30)	37.6	47.3	260.6 (255)
4	23.9 (30)	31.2	30.9	148.7 (255)

Table 4.22: Samarkand – Dahbed Well Field Pumps – BEP

Best Efficiency Point

Pump No.	Pump Head (m)	Power to Motor (kW)	Overall Efficiency (%)	Pump Flow (m^3/h)
1	25.2	29.8	44.8	194.4
2	36.0	30.1	49.8	128.0
4	23.9	31.3	30.9	148.7

Table 4.23: Samarkand – Dahbed Well Field Pumps – BEP – Comparison & Shortfall

Best Efficiency Point – Comparison and Shortfall

Pump No.	Current Flow m3/hr	Current Efficiency %	Anderson Efficiency %	Expected Efficiency %	% Shortfall to Expected Efficiency
1	194.4	44.8	68.0	63.0	-28.96
2	128.0	49.8	68.0	63.0	-20.6
4	148.7	30.9	68.0	63.0	-50.8

Chupanata Final

4.31 This pump is just over one year old, is in very good condition and has a high efficiency in the order of 83.5%. The performance is very close to that tested in the manufacturer's works. Whilst the pumps are pretty well matched to duty, the motors are undersized, probably because the design duty point of the points was slightly higher up the pump curve than the actual duty point. The pumps are therefore operated throttled to prevent motor overload. This is a design fault applying to all of the Chupanata Final Pumpsets. It may be possible to trim the impellor to avoid motor overload whilst allowing the pumps to run un-throttled at a high efficiency.

Table 4.24: Samarkand –Chupanata Final Pumps – Operating Point

Operating Point

Pump No.	Pump Head (m)	Power to Motor (kW)	Pump Efficiency (%)	Pump Flow (m3/hr)
1	85.1 (95)	1,301.4	83.5	4,574.6 (4,000)

Table 4.25: Samarkand –Chupanata Final Pumps – BEP

Best Efficiency Point

Pump No.	Pump Head (m)	Power to Motor (kW)	Pump Efficiency (%)	Pump Flow (m^3/h)
1	89.1	1,269.3	84.0	4,282.9

Table 4.26: Samarkand – Chupanata Final Pumps – BEP – Comparison & Shortfall

Best Efficiency Point – Comparison and Shortfall

Pump No.	Current Flow m3/hr	Current Efficiency %	Anderson Efficiency %	Expected Efficiency %	% Shortfall to Expected Efficiency
1	4,282.9	84.0	89.5	84.5	-0.7

Dahbed Final

4.32 Dahbed Final Pumps 2, 5 and 6 have reasonably good efficiencies in the order of 70%, are well matched to the system and could probably be refurbished to a good standard. Final pump 3 is showing signs of severe wear. Variable speed pumpsets are normally appropriate for pumping into a closed distribution system but are impractical in larger sizes – a multiple pump arrangement is probably the most suitable.

Table 4.27: Samarkand – Dahbed Final Pumps – Operating Point

Operating Point

Pump No.	Pump Head (m)	Power to Motor (kW)	Pump Efficiency (%)	Pump Flow (m3/hr)
2	106.4 (125)	649.2	71.5	1,536 (1,250)
3	116.1 (125)	613.2	64.0	1,189 (1,250)
5	134.2 (95)	604.8	69.5	1,102 (4,000)
6	104.7 (125)	714.7	67.9	1,631 (1,250)

Table 4.28: Samarkand – Dahbed Final Pumps – BEP

Best Efficiency Point

Pump No.	Pump Head (m)	Power to Motor (kW)	Pump Efficiency (%)	Pump Flow (m^3/h)
2	116.8	616.1	72.9	1,354
3	122.3	583.8	65.1	1,094
5	128.3	663.6	72.7	1,323
6	117.8	653.2	71.0	1,387

Table 4.29: Samarkand – Dahbed Final Pumps – BEP – Comparison & Shortfall

Best Efficiency Point – Comparison and Shortfall

Pump No.	Current Flow m3/hr	Current Efficiency %	Anderson Efficiency %	Expected Efficiency %	% Shortfall to Expected Efficiency
2	1,354	72.9	87.5	82.5	-11.64
3	1,094	65.1	87.5	82.5	-21.09
5	1,323	72.7	87.5	82.5	-11.6
6	1,387	71.0	87.5	82.5	-13.94

Moulien Pumping Station

4.33 The pumpsets are in good condition and well matched to the system. They are capable of giving a high efficiency. Presently pump 2 has an efficiency of 77% but the pump is only giving an efficiency of 57 % due to a suspected blockage in the suction main. This should be investigated at the earliest opportunity – the lost efficiency to the pump is expensive.

Table 4.30: Samarkand – Moulien Pumps – Operating Point

Operating Point

Pump No.	Pump Head (m)	Power to Motor (kW)	Pump Efficiency (%)	Pump Flow (m3/hr)
2	49.0 (55)	381.5	77.2	2128.1 (3200)
4	36.9 (55)	382.7	56.8	2089.4 (3200)

Table 4.31: Samarkand – Moulien Pumps – BEP

Best Efficiency Point

Pump No.	Pump Head (m)	Power to Motor (kW)	Pump Efficiency (%)	Pump Flow (m^3/h)
2	53.8	381.5	77.9	1955.3
4	57.4	382.4	73.4	1790.2

Table 4.32: Samarkand – Moulien Pumps – BEP – Comparison & Shortfall

Best Efficiency Point – Comparison and Shortfall

Pump No.	Current Flow m3/hr	Current Efficiency %	Anderson Efficiency %	Expected Efficiency %	% Shortfall to Expected Efficiency
2	1955.3	77.9	88.2	83.2	-6.37
4	1790.2	73.4	88.2	83.2	-11.6

Sogdiana Pumping Station

4.34 These pumps are worn, but despite being of different sizes operate close to the system requirements. Both have a fair efficiency commensurate with age, duty and maintenance. The pumping station installation is poor, and because the pumps are relatively small with tolerable efficiencies refurbishment is not recommended. Complete refit of the pumping station with a duty/standby pair of variable speed drives at a future date is advised. The timing of this refit is linked to improvements in the distribution system. Once existing hydraulic restrictions within the distribution system have been resolved so that the service reservoirs are able to operate normally through the diurnal cycle, these pumps will operate throughout the 24 hour period, whereas at the moment they operate some 2 hours a day. At this time, the existing pumps will have reached the end of their useful life and should be replaced.

Table 4.33: Samarkand – Sogdiana Pumps – Operating Point

Operating Point (Advised Duty Point)

Pump No.	Pump Head (m)	Power to Motor (kW)	Pump Efficiency (%)	Pump Flow (m3/hr)
2	63.0 (63)	128.9	66.5	466.7 (500)
3	69.4 (70)	139.5	67.4	465.4 (720)

Table 4.34: Samarkand – Sogdiana Pumps – BEP

Best Efficiency Point

Pump No.	Pump Head (m)	Power to Motor (kW)	Pump Efficiency (%)	Pump Flow (m^3/h)
2	65.7	121.2	67.1	424.4
3	75.8	136.1	68.1	420.2

Table 4.35: Samarkand – Sogdiana Pumps – BEP – Comparison & Shortfall

Best Efficiency Point – Comparison and Shortfall

Pump No.	Current Flow m3/hr	Current Efficiency %	Anderson Efficiency %	Expected Efficiency %	% Shortfall to Expected Efficiency
2	424.4	67.1	84.5	79.5	-15.6
3	420.2	68.1	84.5	79.5	-14.5

Microrayon Pumping Station

4.35 Both pumpsets are operating at low efficiencies – slightly above 50%. This is because they are worn and not operating at the designed duty points.

4.36 They should be replaced with a new duty/standby pair of variable speed units able to work efficiently to a changing distribution system characteristic. The timing of this refit is linked to improvements in the distribution system. Once existing hydraulic restrictions within the distribution system have been resolved so that the service reservoirs are able to operate normally through the diurnal cycle, these pumps will operate throughout the 24 hour period, whereas at the moment they operate some 2 hours a day. At this time, the existing pumps will have reached the end of their useful life and should be replaced.

Table 4.36: Samarkand – Mircrorayon Pumps – Operating Point

Operating Point (Advised Duty Point)

Pump No.	Pump Head (m)	Power to Motor (kW)	Pump Efficiency (%)	Pump Flow (m3/hr)
3	56.1	83.5	54.0	272.0
5	51.4	291.7	51.7	1016.1

Table 4.37: Samarkand – Mircrorayon Pumps – BEP

Best Efficiency Point

Pump No.	Pump Head (m)	Power to Motor (kW)	Pump Efficiency (%)	Pump Flow (m^3/h)
3	77.8	81.9	63.7	184.8
5	73.3	258.6	66.3	812.2

Table 4.38: Samarkand – Mircrorayon Pumps – BEP – Comparison & Shortfall

Best Efficiency Point – Comparison and Shortfall

Pump No.	Current Flow m3/hr	Current Efficiency %	Anderson Efficiency %	Expected Efficiency %	% Shortfall to Expected Efficiency
3	184.8	63.7	82.1	77.1	-17.4
5	812.2	66.3	86.3	81.3	-18.5

5

Energy Usage

Tariffs

5.1 The cost of energy in Uzbekistan remains very cheap, representing a cheaper comparative to the general cost of living than in the west. That said energy and salaries are the largest costs for the Vodokanals. A reduction in energy costs will of course be of great benefit. The tariffs and energy usage are given in the following tables.

5.2 There is a single day tariff with no differentiation between daytime and nighttime electricity usage. There are different tariffs for high voltage and low voltage supplies and for supply capacities above 750 kW. In accordance with normal electricity utility practice a charge is made for the capacity of the electricity supply provided. On occasions, at the Treatment Works the electrical load would seem to exceed the declared supply capacity. This means that the Vodakanals might be paying slightly less than could be demanded of them by the Electricity utility.

Process Energy Usage

5.3 Over 95% of electrical energy used in the Vodakanals is for pumping water. Other water treatment processes used by the Vodakanals are rapid gravity filtration and chlorination of the final water. These processes are not energy intensive. Super chlorinated water is used to disinfect the final water to supply. This is produced using an electro chlorination process. Sodium Hyperchlorate is produced by passing an electric current through a brine solution. The amount of electricity used is in the order of 10 kWh per Ml, which is small compared to pumping usage and typical for the process.

Energy Metering

5.4 The energy metering which determines the Vodakanal's electricity bills is owned and operated by the Electricity Utility. The Vodakanals could install quality check meters at their own cost. These might show that the electricity company's meter was reading low. In the field survey, equipment was taken to check the meters but this would have required shutting down the treatment works to safely make the necessary connections. In Buchara connections would need to have been made to the electricity utility's apparatus with it switched off. It was not possible to arrange this. A visit was made to a major grid supply point sub-station feeding Buchara and Ku Mazar pimping station. The sheets for recording the power usage for Ku Mazar were seen. It was understood that the same sort of energy meter is used in the electricity utility as in the Vodakanals. It is very unlikely that the meters are routinely calibration checked and there was no supporting anecdotal evidence. The cost for purchasing and installing check meters on two incomers is estimated to be $10,000 per site using local labour.

Bukhara

5.5 In Bukhara a total of 42 MWh of electricity costing 254,825,350 Sum or US$364,036 (exchange rate of 700 sum / US$) is used at the raw water pumping station at Ku Mazar and the treatment works at Shrokrud and Zaravshan. The energy metering on the incomers at Ku Mazar and Shokhrud was not operating. The electricity supply utilities meters at the electricity substations were used. These were read monthly jointly by the electricity utility and water company staff. The energy metering on the 6kV incomers at Zaravshan was operating and used for bill determination. Both active (kWh) and reactive (kVAr) components are recorded. The energy used by the water supply pumping stations in Bukhara during 2001 was:

Table 5.1: Bukhara – Energy Usage 2001

Month	Shokhrud (kWh)	Zaravshan (KWh)	Ku Mazar (kWh)	TOTAL
January	1,594,800	287,719	1,494,000	
February	1,368,000	43,635	1,375,200	
March	1,080,000	216,065	982,800	
April	1,166,400	58,277	2,242,250	
May	986,400	160,277	1,839,600	
June	1,072,800	563,708	2,111,600	
July	1,530,000	1,877	2,323,800	
August	1,461,600	148,843	1,742,400	
September	878,400	1,533,195	1,864,800	
October	1,188,000	296,032	1,792,800	
November	828,000	58,697	2,874,400	
December	1,342,800	47,210	1,245,600	

Less irrigation pumps – fixed agreed figure			300,000	
TOTAL	14,497,200 (14,500 MWh)	3,415,535 (3,400 MWh)	23,889,250 (23,900 MWh)	41,801,985 (41,800 MWh)

5.6 The unit cost for energy usage during the year 2001 was:

Table 5.2: Bukhara – Energy Tariffs 2001

	Declared Supply Capacity (kW)	**Cyms/kW capacity 1/1/01 - 31/7/01**	**Cyms/kw capacity 1/8/01 – 31/12/01**	**Cyms/kWh 1/1/01 - 31/7/01**	**Cyms/kWh 1/8/01 – 31/12/01**
Shokhrud	1,700	816.67	1,066.66	4.40	5.90
Zaravshan	500	816.67	1066.66	4.40	5.90
Ku Mazar	2,800	816.67	1,066.66	4.40	5.90

Annual Electricity Cost in 2001

Table 5.3: Bukhara – Energy Cost 2001

	Cost of Electricity (Cyms)	**Cost of Electricity (Dollars)**
Shokhrud	91,120,863	130,173
Zaravshan	23,679,315	33,828
Ku Mazar	140,025,172	200,036
TOTAL	254,825,350	364,036

Samarkand

5.7 In Samarkand a total of 69 MWh of electricity, costing 376,797,787 Cyms ($538,282), is used by the two main pumping stations and booster pumping stations. Details of energy usage and supply tariffs for 2001 for the major sites were provided by the Vodokanal.

5.8 The supply utility meters on each incomer to the sites monitor use of electricity. There are usually two 6000v or 10000v incomers to each site and both active and reactive component kWh/kVAr meters on each. There is a single day tariff with no differentiation between daytime and nighttime electricity usage. The tariff does change depending on the season of the year. There are different tariffs for high voltage and low voltage supplies and for supply capacities above 750 kW.

5.9 The lack of sufficient income to the Vodakanal and the high energy bill has resulted in only about half of the amount invoiced by the electricity company being paid. The Vodakanal presently owes a considerable sum (believed to be about 400 million Cyms) to the electricity company and this debt is growing. The energy used by the largest water supply pumping stations in Samarkand during 2001 is given in the table below:

Table 5.4: Samarkand – Energy Usage 2001

Site	KWh 1/1/01 - 31/7/01	KWh 1/8/01 – 31/12/01	Total KWh For 2001
Mouleon	1,966,680	681,840	2,648,520
Microrayon	508,200	163,640	671,840
Sogjiana	388,920	219,976	608,896
Octianiskaya	172,656	140,350	313,006
Chuponata	29,962,320	8,835,120	38,797,440
Dahbed	19,562,000	6,160,800	25,722,800
Gagarin	126,120	11,400	137,520
Gormolzavoa	310,080	83,048	393,128
TOTAL			**69,293 MWH**

5.10 The unit cost for energy usage during 2001 was:

Table 5.5: Samarkand – Energy Tariffs 2001

	Supply Capacity (kW)	Cyms/kW capacity 1/1/01 - 31/7/01	Cyms/kw capacity 1/8/01 – 31/12/01	Cyms/kWh 1/1/01 - 31/7/01	Cyms/kWh 1/8/01 – 31/12/01
Mouleon	630	958.33	1,066.66	5.15	5.9
Chuponata	4,200	958.33	1,066.66	5.15	5.9
Dahbed	2,900	958.33	1,066.66	5.28	6.05

5.11 The unit cost for the remaining Low Voltage Booster Stations was 8.75 Cyms and 10.0 Cyms per kWh for the periods before and after 1 August 2001 respectively.

Electricity Cost of the three largest pumping stations (2001)

5.12 The annual cost of electricity for the largest three sites is given. The remaining sites are much smaller and have considerably lower energy costs.

Table 5.6: Samarkand – Energy Cost of the three largest pumping stations (2001)

	Cost of Electricity (Cyms)	**Cost of Electricity (US$)**
Moulien	15,427,002	22,038
Chuponata	214,938,114	307,054
Dahbed	146,432,671	209,189
TOTAL	376,797,787	**538,282**

6

Performance Indicators

Use of Performance Indicators

6.1 Performance indicators (PI) are widely used as tools in many sectors of industry around the world.

6.2 Water undertakings need to strive for good efficiency and effectiveness to achieve their management goals. Efficiency means the extent to which the resources of a water undertaking are utilized to optimally deliver the service. Effectiveness means the extent to which specifically and realistically defined objectives are achieved.

6.3 Energy is one of the highest costs in a water undertaking. Excess energy is used through:

- Inefficient pumping plant.
- Leakage.
- Inefficient energy using process plant.
- High frictional losses in water transmission and distribution systems.
- Poor system operation.

6.4 This study has focused on the efficiency of the pumping plant. Leakage also has a major effect on the total energy used to process water and deliver it to the customer – clearly the more water that is pumped then the higher the electricity bill. Poor system operation can result in higher than necessary frictional losses through throttled valves, unnecessary pumping and failure to use low friction routes within the distribution network. Frictional losses in water transmission and distribution systems are usually design and network analysis matters resolved through investment.

6.5 The concept of performance based Management Contracts requires clearly determined performance standards and targets, which the operator has to achieve. Since energy reduction is always an important issue, the selection of an appropriate indicator is crucial.

6.6 When selecting the energy indicator, other important objectives have to be considered:

- The (very often) required improvement of supply continuity.
- Possible needs to increase operating pressures.
- The expected leakage reduction.
- The improvement of system efficiency (e.g. mains replacement and thus enhancement of hydraulic system characteristics).

6.7 During the preparation of the recent Management Contracts in Central Asia appropriate PIs for leakage reduction and improvement of the supply continuity were developed and applied. Clearly, if leakage is reduced energy consumption will decrease too.

6.8 What does this mean? Assuming that the reduction of the total energy bill would be used as performance indicator the Contractor might be able to achieve reduction targets simply by reducing leakage (for which he already gets his bonus based on the leakage reduction targets) without improving the efficiency of a single pump.

6.9 On the other hand, improving the supply continuity (and/or increasing operating pressure) can easily offset enormous efforts to improve pump efficiency.

6.10 Thus it is necessary to use an indicator which only measures the efficiency gains of pumping stations - irrespectively with other developments (leakage reduction and supply improvement).

6.11 The most appropriate and internationally recognized (IWA[3]) performance indicator relevant to pumping plant efficiency is:

Indicator Ph4 (Standardized energy consumption)**: Wh/m^3 at 100m**

Annual energy consumption for pumping Σ (volume elevated x pump head in hundreds of meters)

[3] Alegre H., Hirner W., Baptista J.M. and Parena R. (2000) Performance Indicators for Water Supply Services. IWA Manual of Best Practice. ISBN 900222272

6.12 Using this indicator, it will be possible to set challenging but achievable targets for the operator and accurately monitor the related performance.

Target Setting

General Methodology

6.13 The results of an Energy Efficiency Study, similar to this one, will be sufficient to determine the percentage figure for the improvement (=reduction) of Indicator Ph4 from baseline. However, it will not be possible to baseline all plant before accurate flow and pressure measurement equipment is installed at all pumps. Therefore, the following methodology is suggested:

Step 1: Estimation of Reduction Potential

1. Execution of an energy efficiency study and ***estimation*** of the present Ph4 indicator for all pumping stations (weighted average, using present annual energy consumption as weighting factor).

2. Identification of appropriate rehabilitation/refurbishment/replacement measures.

3. Forecast of the future Ph4 after implementation of the improvement measures (using achievable Ph4 values for the suggested improvements, e.g. 430 Wh/m3 at 100m).

4. Calculation of the Ph4 reduction potential (%).

Step 2: Establishment of annual targets

1. Ensure sufficiency of funds in the rehabilitation fund for the anticipated improvement investments.

2. Elaboration of a realistic implementation time schedule.

3. Determination of annual targets (% reduction form baseline) up to calculated reduction potential.

Step 3: Baselining

1. Installation of flow and pressure meters at all pumps (or pumping stations) during the first (say) six month of the contract.

2. Calculation of the average (weighted) Ph4 baseline value (based on a 30 days monitoring period using the newly installed equipment.

The Situation in Samarkand and Bukhara

Table 6.1: Energy Reduction Potential – PH4 Indicator - Bukhara

Bukhara		Present Annual Energy Consumption [MWh]	**Estimated Average Ph4 [Wh/m3 at 100m]** Actual	Future
Kuamazar	Final	23,900	482	430
Zaravshan	Final	2,550	599	430
Zaravshan	Intake	850	444	430
Shokrud	Intermediate	3,452	411	411
Shokrud	Final	11,048	564	430
Ph4 Weighted Average			**504**	**428**
Reduction			**15%**	

6.14 At present, Bukhara has an estimated weighted average of 504 Wh/m3 at 100 m. By implementing the suggested improvement measures in Kuamazar, Zaravshan and the Final pumps at Shokrud (assuming that all of them will afterwards be in the range of 430), the overall average Ph4 will be in the range of 428 Wh/m3 at 100 m - a reduction of 15%. The annual split of these 15% (for example 5, 10 and 15 % reductions from baseline during year 2, 3, and 4) will of course depend on the implementation schedule.

6.15 An even bigger reduction potential can be found in Samarkand, where Ph4 could be reduced by as much as 28 % (from 577 to 414) - simply by changing all pumps in the two well fields.

Table 6.2: Energy Reduction Potential – PH4 Indicator - Bukhara

Samarkand		Present Annual Energy Consumption [MWh]	**Estimated Average Ph4 [Wh/m3 at 100m]** Actual	Future
Chupanata	Well	12,909	937	430
Chupanata	Final	25,891	401	401
Dahbed	Well	8,657	937	430
Dahbed	Final	17,043	417	417
Moulien	Booster	2,650	431	431
Sogdiana	Booster	609	435	435
Microrayon	Booster	670	553	553
Ph4 Weighted Average			**577**	**414**
Reduction			**28%**	

6.16 Using this indicator, international comparisons will also be possible - Bristol Water's system for example has a Ph4 of around 385 Wh/m3 at 100m, which might be slightly above average UK water utilities.

7

Investment Program

Sustainability

7.1 A sustainable financial position will only be achieved by a coordinated combination of improvements to the Vodokanal's systems including at least, revenue metering, control of leakage, investment in new plant, network reinforcement, and improved network operation determined from analysis.

7.2 The cost of electricity in Uzbekistan is still relatively cheap. It is not readily possible to financially justify capital investment in new plant at western prices when the sums that will be saved in Uzbekistan currency are relatively very small. There is no doubt that much of the pumping plant in Samarkand and Bukhara urgently requires replacement or refurbishment. This would result in energy saving, reliability and extended asset life. Even greater energy savings would be achieved by reducing leakage within the distribution system and thus the energy needed to pump water into it.

7.3 A substantial investment has already been made in new Ingersoll/ABB pumpsets at Chuponata Treatment works (French Project). The associated switchgear is manufactured by GEC Alstom. The complete system was engineered and installed by Degremont of France. The Vodakanal management and maintenance staff are very concerned they will not be able to keep this equipment well maintained. They have poor access to support services speaking Russian, they have insufficient money to purchase spare parts at western prices and they have little experience and possibly ability in maintaining the relatively sophisticated switchgear, control and monitoring equipment now installed. At the time of the field mission in April 2002, a motor protection device had failed. A new one was requested and sent from France. It remains unfitted and an expensive new pumpset stands idle because (as the City Vodokanal Director explained) the Vodakanal was unable to afford the customs clearance fee.

7.4 Labour is cheap in Uzbekistan. Whilst technicians may not have the abilities of their western counterparts they are able to operate and maintain traditional plant especially if they can get good technical support in their own language. With strong technical management and support they could progress to more sophisticated systems in due course. Presently, sophistication is unjustified. The new computer based telemetry system for monitoring the well pumps at Chuponata is an excellent piece of engineering. It is probably does not substantially improve the level of service or reduce costs. Indeed if maintained correctly it will actually increase costs because western sourced spare parts are, in Uzbekistan terms, very expensive. Presently the Vodakanals cannot even afford a quality motor rewind from a reputable contractor in their own country.

The Refurbishment Option

7.5 Whilst the pumping stations and treatment works look in an appalling condition there is life left in some of the pumping plant. Many of the pumps are sized incorrectly and the motors are in very poor condition. There is also an excessive amount of pumping plant, needed for standby because of the frequent motor failures and present poor matching to system. Rather than replace the pumps, the better ones could be refurbished and trimmed to the correct operating duty. They should be fitted with new motors. If the "core" plant could be made reliable the excess plant could be scrapped. A careful detailed costing exercise would need to be undertaken to determine the difference between complete replacement with new and refurbishment. The problem with complete renewal would mean that probably all of the plant, electrical switchgear as well as pipework would need to be replaced – probably an expensive option.

Procurement of New Plant for the Vodakanals

Variable Speed Drives

7.6 Variable speed pumps have not been proposed for the treatment works final pumps, although they would give efficiency savings by closely controlling the speed of the pumps against a set point pressure. The size of the pumps in most cases is best suited to high voltage motors. High voltage variable speed drives would be difficult for the Vodokanals to maintain and they are presently not as reliable as low voltage variable speed drives. Multiple pump arrangements are the most appropriate solution under the given circumstances for the large pumping stations. The smaller block level booster pumping stations would certainly benefit from variable speed drives. The size of pumps means that low voltage units could be used. Good quality units are now considered to be very reliable but when they fail specialist knowledge is required.

General Procurement Clause

7.7 New equipment specifications should require that telephone technical support and manuals are available in Russian and that the delivery logistics and costs of all spares are detailed in the equipment supplier's proposal document. A list of recommended spares should also be provided. Similarly the arrangements for site support visits and training should be detailed and costed. The equipment supplier shall be required to give an optional price for an extended guarantee on all components except consumables.

7.8 Care should be taken in drafting the specifications for new plant to take into account the limited maintenance facilities, general access to international support, present technical ability and operating budget in the Vodakanals. Emphasis should be on simple or otherwise proven very reliable equipment. Automation should generally be limited to plant protection only. Whilst ubiquitous in the west, use of computers or programmable logic controllers (PLCs) for plant control is discouraged. Level, flow and pressure instrumentation should be installed with local readouts and facility to connect to a telemetry system at a future date. Initially logging of data can be done manually.

7.9 The procurement order must include spare level/pressure transducers and local readout units. Magnetic flowmeters are advised because of their accuracy and reliability. Spare primary coil units are not required but spare secondary readout units should be supplied. It is a management issue to ensure that these spares are kept for the purpose intended and not traded.

7.10 The detailed specification for new plant will be determined at the time of system design. The following example is offered to assist the designer specify Axially Split Casing Pumps. The specification requires easily maintained components such as packed glands and the materials should give longevity. Care is taken in the motor sizing to avoid overload over all operating conditions. A set of specifications tailored for FSU countries and covering a range of equipment could be prepared.

Example Specification - Axially Split Casing Pumps

7.11 All pumps shall be self-priming. The speed of any main pump shall not exceed 1,450 rpm without approval of the Purchaser.

7.12 Pump casings shall be of substantial construction to give long life under abrasive or corrosive conditions. They shall be designed so that the rotating assemblies and bearing can be removed without dismantling the pipework and fittings. Renewable casing wear rings shall be fitted. Integral suction and discharge flanges shall be provided and integral lifting lugs shall be incorporated.

7.13 The impeller shall be readily withdrawable from the pump casing without the need to disconnect the adjoining pipework and with the minimum disturbance of pump drive shafting. Each impeller shall be a one piece casting. Impellors for potable/raw water use shall be of stainless steel, bronze or gunmetal. Impellers shall not be pinned to the shafts neither shall shaft rotation be relied upon to ensure that the impeller is locked in position.

7.14 Pump shafts shall be forged from a material compatible with the impellers. Pumps shall be fitted with packed glands and the shafts fitted with replaceable sleeves where they pass through the gland. Pumps may be fitted with mechanical seals with the prior written approval of the Purchaser. They shall be designed for easy adjustment and seal removal. Effective means shall be provided for collecting gland leakage water and piping this to a floor drain.

7.15 The rotating assemblies shall be statically and dynamically balanced. Impellers and pump shafts shall be statically balanced as individual units. After assembling the impeller on the shaft the rotating assembly shall be dynamically balanced. Impellers, as far as practicable, shall be hydraulically balanced to reduce end thrust on the bearings to the minimum possible.

7.16 Pump bearings shall be designed for a service life of not less than 10^5 hours. Bearings shall be designed for loadings 25% in excess of calculated maximum loading. Bearing cooling arrangements if used shall be designed on the closed-circuit principle. Open discharge of cooling water into the pumping station drainage system is not permissible. The coolant flow shall be easily visible and local indication of bearing temperature shall be provided. Lubrication arrangements shall be designed to avoid any contamination of the pumped fluid.

7.17 The head/quantity characteristic of any pump shall be stable at all rates of flow between closed valve and open valve and shall be steep enough to permit satisfactory operation in parallel under all conditions specified even if this necessitates the use of a larger motor. For pumps which have a power vs. flow rate curve which rises with flow rate through out the operating range of the pump, the motor shall be rated to accommodate high “run out” flows without overload. In any case, as it is possible that the performance of a pumpset will deteriorate over time due to corrosion and general wear, the motor shall be sized such that the shaft power is at least 110% of the maximum power absorbed by the pump over its operating range.

7.18 The pump efficiency shall be maintained within 15% of maximum efficiency over the whole of the specified duty range. The NPSH requirements of the pumps, based on the 3% output drop criterion shall be at least 1.5 m less than the NPSH available at every working condition.

7.19 Water velocities in the pump suction branches shall not exceed 2 m/s and those in delivery branches shall not exceed 3.5 m/s when the pump is operating within its specified duty range and within this working range there shall be no discernible noise due to hydraulic turbulence or cavitations within either the pump or its associated pipe work and valves.

Criteria used to determine the Priority of the Investments

7.20 The principal purpose of this study is to determine the efficiency of energy consuming plant and to propose investments which will reduce operating costs. We have split the investments into “Priority” and “Medium Term” to meet the requirement of the Terms of Reference, however this split is somewhat artificial in that all the investments we have identified are required to ensure satisfactory operation in the medium term and the split between Priority and Medium Term ultimately reflects the availability of funds. Investments have been identified as “Priority” if the plant is at risk of early failure or the investment will result in significant efficiency improvement. Renewal of the electrical switchgear is essential in the medium term (about 3 years) but this will not give an efficiency improvement –

the investment will simply enable the pumping station/treatment works to keep operating. “Sweating the asset” makes good financial sense but this can only done for so long - until the asset “breaks” irreparably or until the maintenance costs exceed the discounted cost of replacing the asset with new. The first of these is close. In the West the switchgear would have already been replaced due to the risk of catastrophic failure and failing to meet safety standards. Unless this equipment is replaced in the medium term (about 3 years), a major failure is likely, resulting in widespread sustained supply interruptions.

7.21 Similarly replacement of the electrical protection equipment would not produce any operating cost savings. The purpose of such equipment is to automatically “switch off” plant under poor electricity supply conditions or in the event of a fault on the plant itself. This is to prevent catastrophic damage to the plant and to clear conditions which could be dangerous to personnel. Protection equipment will isolate faulty plant and leave serviceable plant running. Whilst the equipment aesthetically appears to be in an appalling condition, the Vodakanals assure that it is tested regularly. At Buchara the specialist to whom the protection testing and repair work is outsourced was interviewed and judged competent. He also undertook similar work for the electricity utility.

7.22 The proposed investments will not have a significant effect on the present level of service interruptions in Samarkand. This is essentially a distribution system problem. The present network between the bulk supply points from the treatment works and the service reservoirs at the block level booster pumping stations is inadequate to meet demand. However, once these problems are rectified the block level booster pumping stations will be required to operate 24 hours a day. The present condition of these pumping stations is very poor and the increased running time may result in early failure.

Proposed Maintenance Budgets

7.23 Maintenance is critical to the continued and efficient operation of pumping plant. Good maintenance requires the right attitude of mind. The more material items are also important but somewhat easier to acquire. Unless a positive, proactive “maintenance culture” is established, money spent on tools etc will be wasted. A proactive maintenance culture embodies the ethos – if it is dirty, clean it, - if it is about to break mend it before it does, if is broken then either mend it or scrap it and make good, – what ever it is do it with pride and professionalism. This is a management issue and cultural change does cost, but possibly not in the annual maintenance budget.

7.24 As the equipment becomes more complicated and there is drive to increase maintenance standards, it is expected that the Vodakanals will increasingly outsource specialist maintenance – this must be budgeted for.

7.25 The estimated maintenance budgets assume local purchase from within Uzbekistan or Former Soviet Union Countries. Excluding manpower the maintenance budget should provide for:

Tools

7.26 Initially the cost of tools will be high but providing “loss” is controlled – subsequent years will be cheaper. Initially each Vodakanal should purchase basic quality tools such as spanners, pliers, cutting tools, screwdrivers, socket sets, drills, drilling bits, files calipers, feeler gauges, micrometers, dial level gauges, soldering irons, crimping tools, die thread cutters, thread tapping tools etc. Initial budget per Vodakanal is estimated at $20,000. Thereafter $5,000 per Vodakanal per annum should be sufficient.

Test Equipment

7.27 Test equipment must be looked after well and periodically calibrated. Initially basic test equipment should comprise: electrical multi-meters, insulation resistance tester, tachometers, phase rotation meters, pressure transducer calibration unit, pressure logger/chart recorder etc. Initial budget per Vodakanal is estimated at $20,000. Thereafter $5,000 per Vodakanal per annum should be sufficient.

Setting up the Maintenance Workshops

7.28 This is a one off cost to prepare a room and install a workbench with good lighting, provide shelves for maintenance and reference manuals, provide lockable cupboards for test equipment, racks for tools, shelves for consumables etc. One off sum – nominally $10,000 per Vodakanal.

Consumables

7.29 This item will include grease, oil, gasket material, insulation tape, PTFE tape, filters, fuses etc.

7.30 Initially allow $6,000 per annum for Buchara and $9,000 for Samarkand.

Spare Parts

7.31 It is difficult to estimate the spare parts requirement without knowing which plant will be renewed. It should include for manufacturer’s recommended spares and other items which are difficult to obtain in Uzbekistan, but have a relatively high risk of failure. Initially allow $20,000 per Vodakanal – this may be too low but can be reviewed when the tenders for supply of new equipment are received.

Outsourced Services

7.32 Typically this includes for motor rewinds, major off site pump repairs, etc Initially allow $30,000 per Vodakanal.

Bought in Technical Support

7.33 It is difficult to estimate the spare parts requirement without knowing what plant will finally be installed. This items includes support for the repair of variable speed drives, electrical protection systems, flowmetering equipment, on-line water quality monitoring equipment, international manufacture high voltage switchgear, international manufacture pumps etc. Initially allow $15,000 for Samakand and $10,000 for Buchara.

Training

7.34 In the early years this will be relatively high until the workforce knowledge/skill base is up to the required standard. The new system operator will have a significant role here and the amount of further bought in training will depend on his terms of reference and preferred approach. The nature of the plant that is finally installed will also have a bearing on the training required – some international assistance may be necessary. A nominal sum of $10,000 per Vodakanal is proposed.

Protective Clothing

7.35 High voltage gloves, face and head protection, etc allow a nominal $500 per Vodakanal.

Summary of Proposed Annual Maintenance Budget (based on local purchase prices)

Table 7.1: Proposed Annual Maintenance Budget – Bukhara & Samarkand

Item	Bukhara		Samarkand	
	First Year ($)	Subsequent Years ($)	First Year ($)	Subsequent Years ($)
Tools	20,000	5,000	20,000	5,000
Test Equipment	20,000	5,000	20,000	5,000
Setting up the maintenance workshops	10,000		10,000	
Consumables (gaskets, grease etc)	6,000	6,000	9,000	9,000
Spare parts	20,000	20,000	20,000	20,000
Outsourced services (motor repairs etc)	30,000	30,000	30,000	30,000
Bought in technical support (variable speed drive repairs)	10,000	10,000	15,000	15,000
Training	10,000	10,000	10,000	10,000
Protective Clothing	500	500	500	500
TOTAL	126,500	86,500	140,500	100,500

Bukhara

7.36 The cost of equipment is based on Western Prices unless otherwise stated. An assumption has been made that local labour will undertake much of the installation work under specialist supervision.

Priority Investment

Ku Mazar

7.37 As already mentioned in the Executive Summary, the Refurbishment of Ku Mazar is the most economic of all investigated investment measures. Table 7.2 below shows data of the four pumps tested, Annual Electricity cost of the entire pumping station as well as investment needed and potential savings.

Table 7.2: Ku Mazar - Possible efficiency gains and associated cost

Ku Mazar	Pump No.	kW	Shortfall from Efficiency
Ku Mazar Final	2	460	-12.5%
Ku Mazar Final	3	519	-3.7%
Ku Mazar Final	5	742	-14.8%
Ku Mazar Final	6	869	-23.8%
Total		2,589	
Average			-13.7%
Weighted Average			**-15.2%**
Present Annual Electricity Cost		US$	200,036
Potential Annual Savings		**US$**	**30,380**
Investment Cost		US$	180,000
IRR after 10 years			**11%**

7.38 An IRR of 11% after 10 years is a convincing argument for this investment.

7.39 The pump-sets at Ku Mazar should be refurbished in a Russian pump manufacturer’s workshop and the impellers trimmed so that the pumps better match the system. This should give an energy saving in the order of 3,600,000 kWh per annum with a corresponding cost saving of some $30,000 per annum.

Shokrud

7.40 Investments in Shokrud cannot be justified by the potential energy savings.

Table 7.3: Shokrud - Possible efficiency gains and associated cost

Shokrud	Pump No.	kW	Shortfall from Efficiency
Shohrud Intermediate	2	508	-16.5%
Shohrud Final	1	813	-19.4%
Shohrud Reserve	2	322	-9.2%
Shohrud Final	3	307	-24.6%
Shohrud Final	5	843	-27.0%
Shohrud Final	7	704	-9.5%
Total		3,498	
Average			-17.7%
Weighted Average			**-18.3%**
Present Annual Electricity Cost		US$	130,173
Potential Annual Savings		**US$**	**23,866**
Investment Cost		US$	1,260,000
IRR after 10 years			**-23%**

7.41 However, if funds are available the final water pumpsets (pumps and motors) at Shokhrud Treatment works should be replaced with four new units sized at 3200 m^3 /hr, at 40m head. All original final pumpsets should be removed. The electrical switchgear should also be replaced to suit. Approximate cost will be US$1,200,000.

7.42 The faulty motor on the Shohkrud Intermediate Pumpset should be repaired, both pumps refurbished and the impellers trimmed to give 5000m3/hr at 15m head. Approximate cost US$60,000.

7.43 Numbers 2 and 3 final pumps removed from Shokhrod (the two pumps which are still in reasonable condition) should be refurbished trimmed and installed at Zaravshan Treatment works to replace faulty existing pumps (see below).

Zaravshan

7.44 The two removed pumps from Shokhrod should be refurbished trimmed to give and optimum duty of 1500m^3 /hr at 35m and installed to replace faulty existing ones. Approximate refurbishing and trimming cost US$30,000. New motors should be fitted to the refurbished pumps at a cost of US$80,000.

7.45 Existing Pump 6 at Zarvsahan should be refurbished and the impeller trimmed to give 1000 m^3/hr at 35m. Approximate cost US$15,000. A new motor should be fitted to the pump at a cost of US$30,000. Zaravshan final pump 3 should be scrapped.

7.46 The Intake pumpsets at Zaravshan should be refurbished and impellers trimmed to give a duty of 1800m^3/hr at 15m head. Approximate cost US$30,000.

7.47 Table 7.4 below shows the possible efficiency gains and associated cost.

Table 7.4: Zaravshan - Possible efficiency gains and associated cost

Zaravshan	Pump No.	kW	Shortfall from Efficiency
Zaravshan Final	6	332	-11.1%
Zaravshan Final	3	204	-38.8%
Zaravshan Intake	1	86	-20.0%
Zaravshan Intake	2	100	-11.6%
Total		722	
Average			-20.4%
Weighted Average			**-20.1%**
Present Annual Electricity Cost		US$	33,820
Potential Annual Savings		**US$**	**6,787**
Investment Cost	US$	US$	185,000
IRR after 10 years			**-15%**

Instrumentation and Buildings

7.48 Flow and pressure logging instruments with local readouts should be installed on all the delivery mains from Ku Mazar, Shokhrud and Zarvshan works. The flowmeters should be full flow magnetic types. These have a higher capital cost than other types but are more reliable and accurate and are overall more suitable for the circumstances in Uzbekistan. Approximate costs US$140,000.

7.49 At low cost the treatment works buildings should be refurbished used using cheap local labour. Particular attention should be given to the leaking roofs.

7.50 The energy metering which determines Vodakanals electricity bill is owned and operated by the Electricity Utility. Vodakanals could install quality check meters at their own cost. The cost for purchasing and installing check meters on two incomers is estimated to be $10,000 per site using local labour.

Medium Term Investment

7.51 New motors should be fitted to all of the refurbished Ku Mazar pumps. Approximate cost US$250,000 using local labour for the installation.

7.52 All electrical switchgear should be replaced at Ku Mazar and Zaravshan. Approximate cost will be US$1,100,000 for Ku Mazar and US$250,000 for Zaravshan.

7.53 Table 7.5 below summarizes all the short and medium term investments for Bukhara.

Summary

Table 7.5: Summary - Investments Bukhara

Location	Equipment	Number	Refurbishment/New	Estimated Cost (US$)
Priority Investment				
Ku Mazar Intake	Raw water pump sets	6	Refurbish & Trim to duty	180,000
Shokrud Treatment Works	Final water pumps & Electrical Switchgear	4	All New	1,200,000
Shokrud Treatment Works	Intermediate Final pump-sets	1 2	New Motor, Refurbish & Trim to duty	30,000 30,000
Zarapshan Treatment Works	Final pumps	2 2	New Motor Pumps Replaced by refurbished Shohkrud pumps	80,000 30,000
Zaravshan Treatment Works	Final pump No. 6	1 1	New Motor Refurbish & Trim to duty	30,000 15,000
Zaravshan Treatment Works	Intake pumps	2	Refurbish & Trim to duty	30,000
Ku Mazar, Shokrud, Zaravsahan	Flow & Pressure Monitoring	7 sets	New Installation	140,000
TOTAL				**1,765,000**
Medium Term Investment				
Ku Mazar Intake	Raw water pump sets	6	Motor	240,000
Ku Mazar Intake	Electrical switchgear & Cabling	1 set	New, Complete High Voltage Switchboard with six motor starters	1,100,000
Zaravshan Treatment Works	Electrical switchgear & Cabling	1 set	New, Complete High Voltage Switchboard with motor starters	250,000
TOTAL				**1,590,000**
.				
Priority & Medium Term Investment				**3,355,000**

Samarkand

Priority Investment

Well Pumpsets at Dahbed and Chuponata

7.54 The well pumpsets at Dahbed and Chuponata Treatment works are the most inefficient pumping plant in the Vodakanal. They are in extremely poor condition have poor reliability. To maintain a water supply to the city they should be replaced **urgently.** On the sample tested they have an average efficiency of slightly less than 40%. The effect of this is not so much a high energy bill but insufficient water to supply the city.

7.55 There are 25 duty well pumpsets at Dahbed (5 stand-by) and 52 at Chuponate (also 5 stand-by) each rated at 32kW making a total installed load of nearly 2.5 MW. From the test results an average efficiency shortfall of about 37% has been determined. Assuming a 75% load factor for the pumpsets this shortfall is the equivalent of 6,100,000 kWh per year.

Table 7.6: Well Pumpsets at Dahbed and Chuponata - Possible efficiency gains and associated cost

Well Pumps	Pump No.	kW	Shortfall from Efficiency
Chupanata Well Field	14	36	-34.9%
Chupanata Well Field	15	37	-53.2%
Chupanata Well Field	17	27	-34.6%
Dahbed Well Field	1	30	-28.9%
Dahbed Well Field	2	38	-20.6%
Dahbed Well Field	4	31	-50.8%
Total		198	
Average			-37.2%
Weighted Average			-37.1%
No. of Well Pumps on Duty		77	
Average power rating (kW)		33	
Assumed load factor		75%	
Annual Power Consumption (kWh)		**16,685,939**	
Present Annual Electricity Cost		US$	140,639
Potential Annual Savings		**US$**	**52,232**
Investment Cost		US$	1,479,000
IRR after 10 years			**-15%**

7.56 A new well pumpset with a duty of 255 m^3 /hr at 20m head will cost in the order of $11,000. New electrical starting equipment (without telemetry/remote monitoring) will cost another $2500. Installation will be required. At western costs this would be about $2000 per pumpset. Is also recommended that new delivery valves are installed at about $1500 per pumpset, thus approximate cost of US$17,000 per well, giving a total of 510,000 for Dahbed and 969,000 for Chupanata. The works could be completed within four months.

General

7.57 The blockage in the suction pipe work to Moulien no 4 pump should be removed. This pump is capable of good efficiency. At low cost it could be restored with planning and use of local labour. Cost will be certainly less than US$1,000.

7.58 Flow and pressure logging instruments with local readouts should be installed on all the delivery mains from Chuponata and Dahbed treatment works. The flowmeters should be full flow magnetic types. These have a higher capital cost than other types but are more reliable and accurate and are overall more suitable for the circumstances in Uzbekistan. Approximate costs $120,000.

7.59 At low cost the treatment works and pumping buildings should be refurbished used using cheap local labour. Particular attention should be given to the leaking roofs. A watertight building at Dahbed should leave no excuse for the disgracefully dirty condition of the main pump hall.

7.60 The energy metering which determines Vodakanals electricity bill is owned and operated by the Electricity Utility. Vodakanals could install quality check meters at their own cost. The cost for purchasing and installing check meters on two incomers is estimated to be $10,000 per site using local labour.

Medium Term Investment

Dahbed

7.61 Completely replace the final water pumping plant including HV switchgear at Dahbed Treatment Works with a design similar to Chuponata but preferably using less sophisticated equipment. Four pumpsets with associated HV switchgear should be installed at an approximate cost of US$1,600,000. As an option the pumps could be refurbished saving about US$200,000 but new motors and switchgear should still be installed.

Table 7.7: Dahbed Final Pumps - Possible efficiency gains and associated cost

Dahbed Final	Pump No.	kW	Shortfall from Efficiency
Dahbed Final	2	649	-21.0%
Dahbed Final	3	613	-11.6%
Dahbed Final	5	605	-13.9%
Dahbed Final	6	715	-6.3%
Total		2,582	
Average			-13.2%
Weighted Average			**-13.0%**
Present Annual Electricity Cost		US$	175,496
Potential Annual Savings		**US$**	**36,854**
Investment Cost	US$	US$	1,600,000
IRR after 10 years			**-20%**

Booster Pumping Stations

7.62 This is certainly the most controversial investment and might only be justifiable once a continuous supply situation will be reached. Only then one would consider completely refitting all six distribution pumping stations (Micrayon, Sogdiana, Gormolsavod, Oktyabrskaya, Gorki, Tolstoi) using a single pair of duty/standby variable speed pumpsets at each site. This is estimated to cost about US$300,000 per site making a total in the order of US$1,800,000. No work is presently required at Moulien Pumping Station.

7.63 Efficiency details see Table 7.8 below.

Table 7.8: Booster Pumping Stations - Possible efficiency gains and associated cost

Booster Pumping Stations	Pump No.	kW	Shortfall from Efficiency
Sogdiana Booster	2	129	-15.6%
Sogdiana Booster	3	140	-14.5%
Micorayon Booster	3	84	-17.4%
Micorayon Booster	5	292	-18.5%
Total		644	
Average			-16.5%
Weighted Average			**-16.9%**
Present Annual Electricity Cost		US$	31,429
Potential Annual Savings		**US$**	**4,903**
Investment Cost	US$	US$	1,800,000
IRR after 10 years			**-39%**

Pumped Storage System

7.64 Consideration should be given to the construction of a master reservoir to be built by local labour on the hills on the outskirts of Chuponata and fed from Chuponata works. As a parallel activity, negotiations should be made with the Electricity Company for low cost nighttime tariffs – this would be to mutual benefit.

7.65 Multiple times of day or the simpler night and day tariffs are usually encouraged by electricity utilities. A tariff system helps to smooth out electricity usage by encouraging consumers to use electricity by making it cheap when demand is low such as at night and likewise expensive when demand is high. Low cost electricity generation plant cannot be quickly started and stopped to meet peak demands so keeping excess plant running just to meet the peak electricity demands is very expensive for the electricity utilities. Unlike electricity water can be stored – there is beneficial partnership here that is used to advantage by utilities throughout the world. Pumps are only needed in a water supply system to give the water kinetic energy such that it moves and can be distributed. The same pumps can give the water potential energy by pumping it to a high reservoir. The water will then gravitate on demand into the distribution system.

7.66 The financial advantage is that pumping plant can operate at a high flow at night time making most use of cheap electricity and filling the reservoir for the following day. The system can be designed such that there is a constant optimum head on the pumping plant allowing the pumps to operate most efficiently rather than riding the pressure/flow curve with varying efficiency as at present with the pumped distribution system.

7.67 A reservoir would also give major water quality and water supply benefits. There are several serious risks with a wholly pumped system. Failure of the pumping plant for any reason (e.g. electricity supply failure) will cause the distribution system to depressurize and possibly have sub-atmospheric pressures in places. Not only will the water supply be lost to the customers but there is the real risk of polluted water being drawn into the sub-atmospheric pipe work and creating a public health hazard. The reservoir also presents a relatively constant head on the system enabling good pressure management control within the distribution system. It provides a source of security water in the event of a major burst or fire – a pumped system might not always be able to meet such an exceptional demand.

7.68 Pumped potable water storage systems are used through out the world but do require conveniently positioned hills or else the construction of multiple water towers (cf Middle East countries), which is very expensive.

Summary

Table 7.9: Summary - Investments Samarkand

Location	Equipment	Number	Refurbishment/New	Estimated Cost (US$)
Priority Investment				
Dahbed	Well pumps	30	New	510,000
Chupanata	Well pumps	57	New	969,000
Mouleon	Booster Pump	1	Local Labour	1,000
Chupanata, Dahbed	Flow & Pressure Monitoring	6 sets	New Installation	120,000
TOTAL				**1,600,000**
Medium Term Investment				
Six Distribution Booster Pumping Stations	Two Variable Speed pumps operating in Duty/Standby mode	6 sets of differing duties	New	1,800,000
Dahbed	Pumpset & Electrical Equipment	4 sets	New	1,600,000
TOTAL				**3,400,000**
Priority & Medium Term Investment				**5,000,000**

8

Dissemination activities

8.1 Considerable change is necessary for the Vodokanals to become sustainable entities. Workshops, "on the tools" training and other dissemination, knowledge transfer activities can have only a very small effect. The most realistic aspiration is that they will raise awareness amongst Vodokanal staff that there is pressure for change and the form that this might take. The problems in Uzbekistan are deep routed and this of course affects the management of the Vodokanals.

8.2 The biggest problem is lack of money. The cash flow is so poor that staff is frequently not paid on time and sometimes not at all. The wages are low and generally (although most certainly not totally) this affects the attitude of all working in the Vodokanals from the top down. Many employees have second or third jobs. At the lower levels time is often not spent productively in the interests of the Vodokanal. This is not because the staff is all incompetent or have poor attitude – but why should they work if they are not getting paid?

8.3 The same problem (lack of money) affects the procurement of spares and quality external services such as motor rewinding. At some locations within the Vodokanals it is known that any tools and spares that might become available will simply be sold to enhance salaries.

8.4 There is no doubt that the staff is capable, receptive and will benefit from learning also to the benefit of the Vodokanals. However, realistically, the difference that dissemination activities can make is small. Dissemination activities on this mission took the form of working with the Vodokanal staff at all levels and conducting formal Workshops.

8.5 Workshops were held in both Bukhara and Samarkand. The Bukhara workshop was well attended with eleven people including the Chief Engineer, Heads of Department and the Treatment Works managers. There was good interest. In Samarkand there was less participation, but the Chief Electrician and Chief Mechanical Engineer did attend and contributed constructively.

8.6 The workshops took the form of power point presentations with ad-hoc explanations/diagrams on flip charts. The participants were invited to question, criticize or otherwise contribute, and generally they did. The topics covered by the workshops included:

- Presentation and interpretation of the Pump Test results.
- Interpretation of pump curves.
- Observations on the general condition of the Treatment Works and Pumping Stations.
- Maintenance regimes.
- Methods of Testing Pump Efficiency.
- Variable Speed Drives.
- The problems of pumping directly into a large distribution system.

8.7 At all stages during the pump testing activities, Vodokanal staff were involved and care was taken to explain to them exactly what was being done and why. The use of two interpreters considerably aided smooth dialogue with operatives and enabled everyone to get the most from the consultant's visit.

8.8 Handouts distributed to the Participants during the workshop are attached in Appendix B.

9

Recommendations on Contract Documents

Terms of Reference for Future Energy Efficiency Studies

9.1 To assist the Bank in preparing terms of references for future energy efficiency studies of this type, the consultant summarizes below recommendations for amendments to the existing terms of reference:

- An energy efficiency study is required prior to letting a management contract in order to determine the energy efficiency performance targets that the Operator has to meet.

- The preparation of specifications for procurement of the equipment proposed in the priority and medium term investments should be included within the terms of reference of the study, because the details of the type of equipment recommended for investment are closely linked to the equipment specifications. It is not possible to provide detailed information on the recommended equipment without preparing specifications. These specifications are also required for the costing study discussed below.

- A costing study should be included to evaluate the alternative options of replacement of plant with refurbishment. Such a costing study would comprise the following elements.

New

- Detailed specification and outline designs for pumping station using existing building but installing new pumping plant, motor control switchgear, new instrumentation and control systems, electrical distribution equipment if necessary.

- Determine the approximate cost of the new installation from supplier's budget quotations and standard price lists.

- Estimate the running cost of the new installation for a given demand profile.

Refurbishment

- Identify the "core" pumping plant for possible refurbishment (the excess standby to be scrapped).

- Obtain budget quotations for refurbishment of the "core" pumping plant.

- Obtain budget quotations for replacement of "core" pumping plant motors.

- Outline design and obtain quotations for installing "suitable" instrumentation and control equipment.

- Estimate running costs of refurbished plant for a given demand profile.

Comparison

- Compare the cost of complete renewal against refurbishment using a discounted cash flow technique over 10 years and assuming complete replacement of the electrical switchgear after 3 years for the refurbishment option.

9.2 We estimate that a study with these expanded terms of reference would take approximately 6 months and cost around US$200k.

Recommendations on Combined Studies

9.3 Experience gained during the preparation of the Management contracts in Tajikistan, Kazakhstan and Uzbekistan showed that the following engineering studies are needed to prepare the budget for the rehabilitation fund and to set meaningful annual performance targets:

- Water production, consumption and water loss (Non-Revenue Water) assessment.

- Pressure monitoring program to determine present supply continuity.

- Energy efficiency study.

- Water production, treatment and quality assessment.

Historical Development

9.4 The need for studies in these fields was only realized during the last few years - all kick-started by the results of the first water loss reduction, production and consumption assessment in Samarkand & Bukhara in 1999.

9.5 At that time, the objectives of the study did not include the preparation of performance targets and thus a separate consulting assignment was required to advise the Client on water loss related target setting and to develop an appropriate methodology.

9.6 Another disadvantage was the split between water production/treatment assessment and water distribution/loss reduction in two different studies, since efficiency gains by demand and water loss management do directly effect the required investment in new treatment facilities.

9.7 These lessons were learned and as a consequence a comprehensive study comprising of production, treatment, demand and water loss reduction assessment was carried out which also included the determination of appropriate performance indicators and targets.

9.8 However, an area which was not paid enough attention was the improvement of supply continuity, which became extremely important during the preparation of the Samarkand performance targets, as the re-establishment of 24h supply had high priority for technical, political and last but not least public health reasons. Immediately it was realized that an appropriate performance indicator was needed and another study was carried out to get a better understanding of the present level of supply continuity (pressure monitoring program).

9.9 Energy efficiency became another critical aspect in the discussion with the Client (during management contract preparation) as expectations for the energy reduction potential were high but unfortunately there was no way to professionally determine potential efficiency gains needed for target setting. Thus a new type of study was born.

Characteristics of the Individual Studies

9.10 Taking all the above developments and experience made into account, the studies are briefly characterized below. Cost and man month figures are indicative only, as they are heavily influenced by size and complexity of system and location (country) of the utility.

9.11 Cost estimates are based on the following:

- Reasonable accessibility of the place (not too far from the next airport).
- Population of town: ~ 500,000.
- Establishment of performance standards and targets is included.
- All studies include workshops to agree issues with the Client.

Water Production, Consumption and Non-Revenue Water Assessment

9.12 Formerly called BABE study (from the “Burst and Background Estimates” methodology), a component based analysis used to quantify the individual components of Non-Revenue Water and elaborate reduction forecasts needed for the preparation of investment strategies.

Total Timeframe:	6 months
Field works:	2 months
Manpower Input:	6 man months
Total Cost:	US$175,000

Pressure Monitoring Program

9.13 System-wide pressure monitoring is a useful tool to baseline the level of supply (supply continuity) before implementing rehabilitation programs. It is required to set relevant targets for performance based contracts. Time and cost needed depends heavily on the complexity of system operations and its present supply problems and characteristics.

Total Timeframe:	4 months
Field works:	1.5 months
Manpower Input:	4 man months
Total Cost:	US$115,000

Energy Efficiency Study

9.14 Experience gained during this study has shown that pump efficiency varies widely, and that most of the pumps have to be tested to assess the energy reduction potential and elaborate appropriate rehabilitation and investment strategies. On top of the scope of this present study, future studies (see recommendations above) have to include the elaboration of detailed specifications for pump replacement/refurbishment.

Total Timeframe:	6 months
Field works:	2 months
Manpower Input:	7 man months
Total Cost:	US$200,000

Water Production, Treatment and Quality Assessment

9.15 This assessment mainly deals with conditions of wells and water treatment facilities, laboratories, treatment and analyses practices and general water quality issues. Scope and thus cost of the assignment are difficult to estimate as raw water quality varies widely, in simple cases with good ground water quality cost will be less but in cases with highly contaminated sources more complex studies might be needed.

Total Timeframe:	4 months
Field works:	0.5 months
Manpower Input:	2.5 man months
Total Cost:	US$75,000

Individual Studies - Summary

9.16 Execution of these four studies in parallel has several disadvantages:

- Optimum timing will be difficult (recruitment of Consultants, mobilization, availability), thus it is likely that that the overall duration will be substantially more than the maximum duration (6 months) of the longest individual study.
- Frequent overlapping:
    - between Leakage and Energy Study: flow measurements at all production facilities, equipment rent and transport;
    - between Leakage and Pressure Study: pressure measurements and equipment rent and transport, familiarization with the distribution system;
    - between Pressure and Energy Study: pressure measurements close to pumping stations, equipment rent and transport;
    - between Water Quality and Energy Study: condition of pumps and equipment in treatment plants and wells.
- Different project teams will have to familiarize themselves with the situation. Thus the Client will frequently have to answer the same questions several times. Constructive co-operation with counterpart staff will become increasingly difficult.
- Conclusions to be drawn are in many cases related on the results of more than one study. The subjects are heavily interrelated.

- Total costs are high. The examples given above add up to US$565.000. Out of that, a substantial amount is spent on project management, travel, equipment rent.

- Client might get confused: different Consultant might come up with very different recommendations. Consistency in the approach is not guaranteed. Client and Legal Consultants will have to deal with a too-big number of specialists during preparation of the RFP document. Further delays are programmed.

Characteristics of a Comprehensive Study

9.17 Combining all of the above-mentioned studies into one clearly offers substantial benefits. Reduced cost (see below) is one of them, but reduced implementation time and more comprehensive and integrated results, recommendations and performance targets are of even greater importance.

9.18 Assuming that the study has to be carried out for a similar system, it's duration and cost were estimated as follows:

Total Timeframe:	6 months
Field works:	3 months
Manpower Input:	12 man months
Total Cost:	US$350,000

Recommendations

9.19 The advantages of the combined study are obvious. Lessons learned during all the individual studies carried out during the last three years should form the basis for the elaboration of model Terms of Reference.

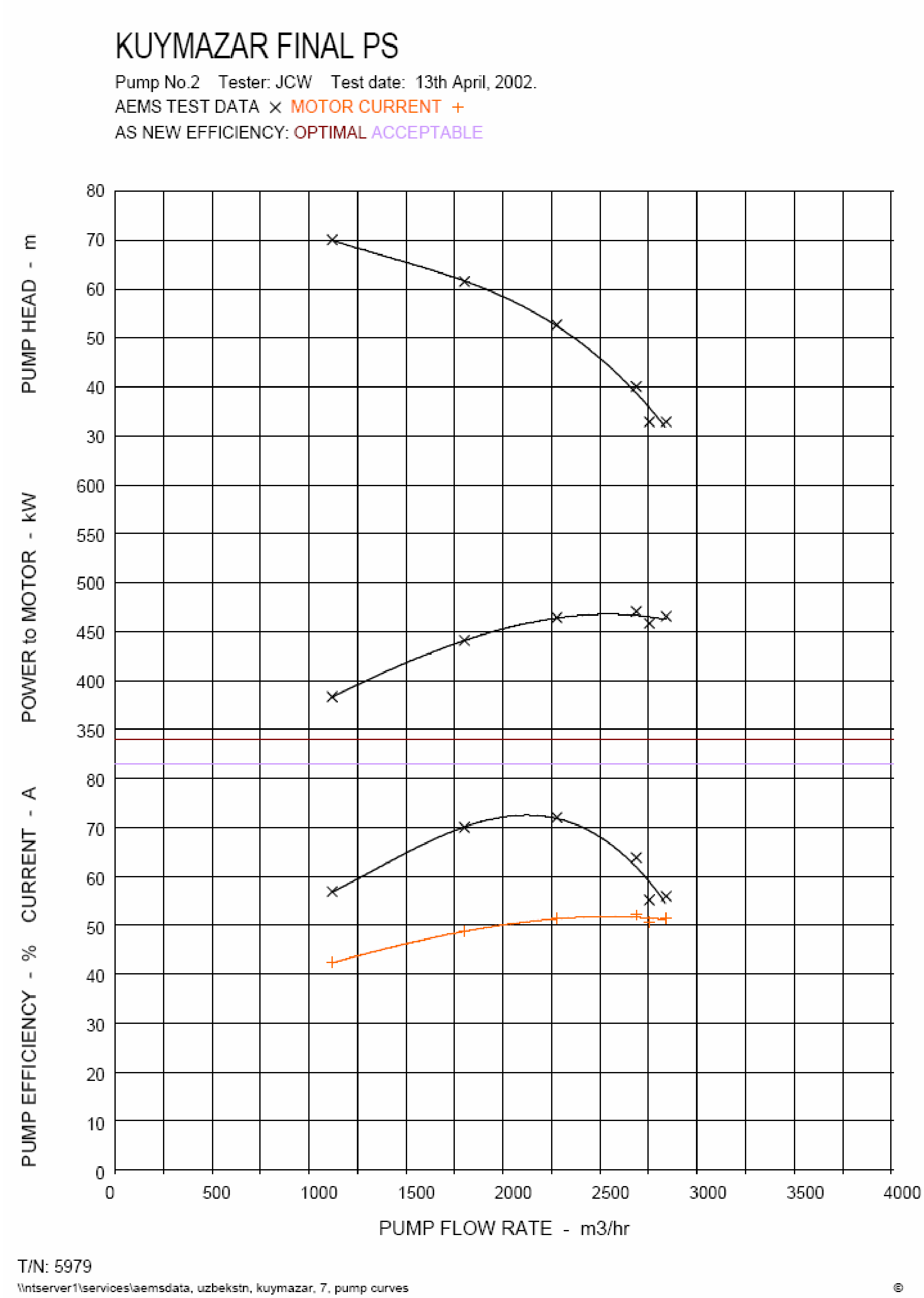
9.20 Since the technology and approach has developed substantially since the first leakage study in Samarkand and Bukhara, a critical review of the presently used ToR should be undertaken. The ToR of the energy assessment has to be modified in any case - be it as new stand-alone ToR or as a part of comprehensive ToR.

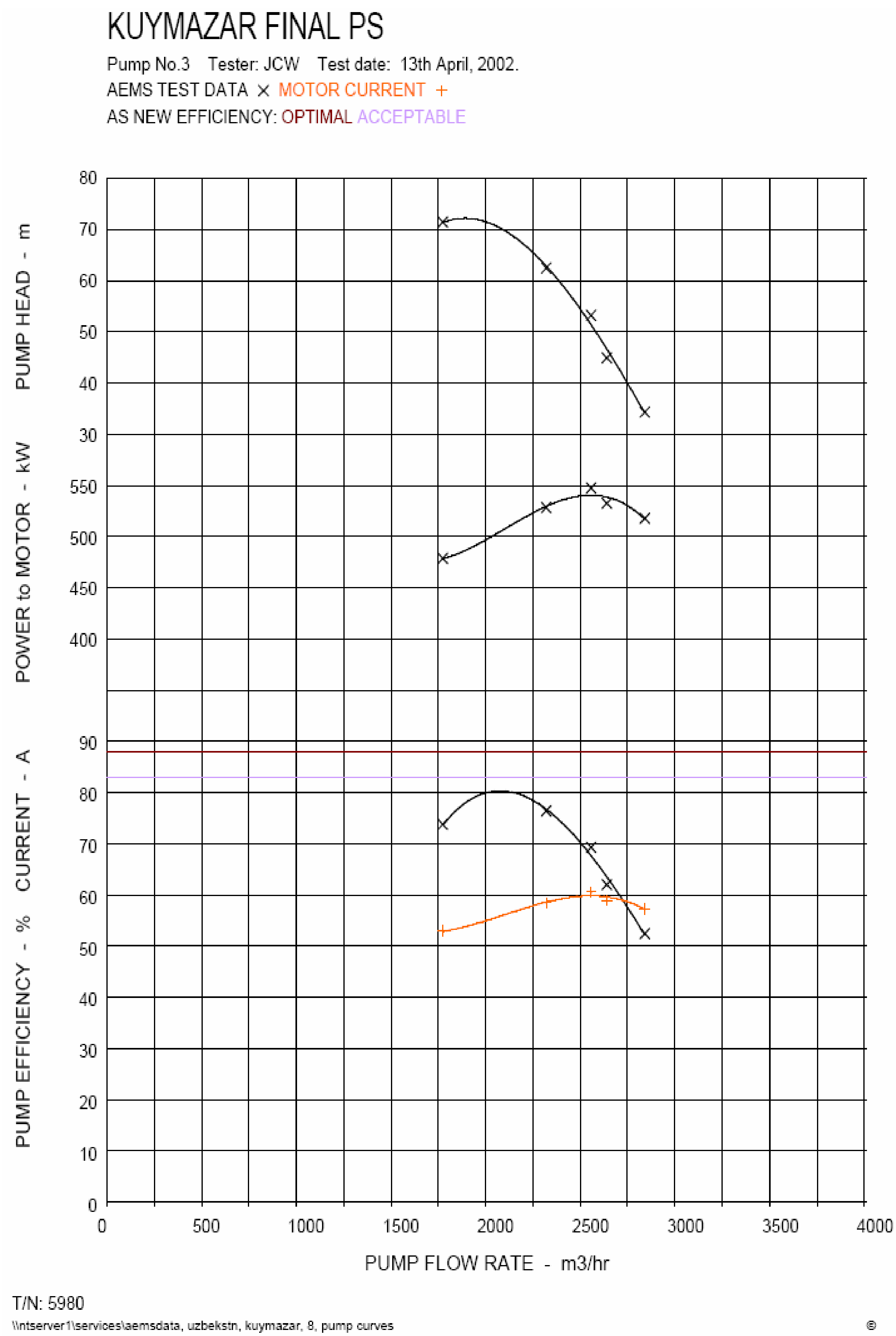
Appendix A

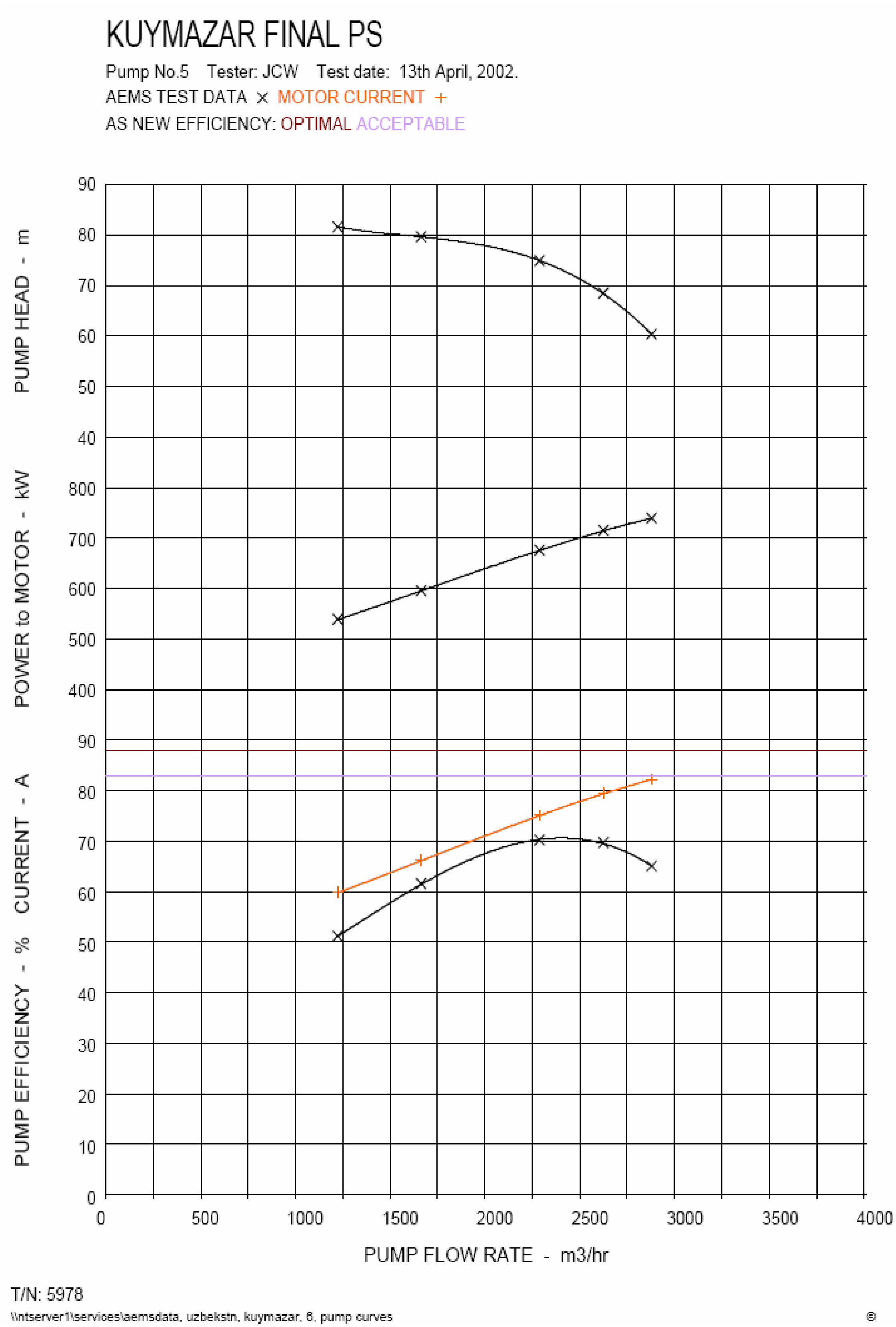
Pump Curves

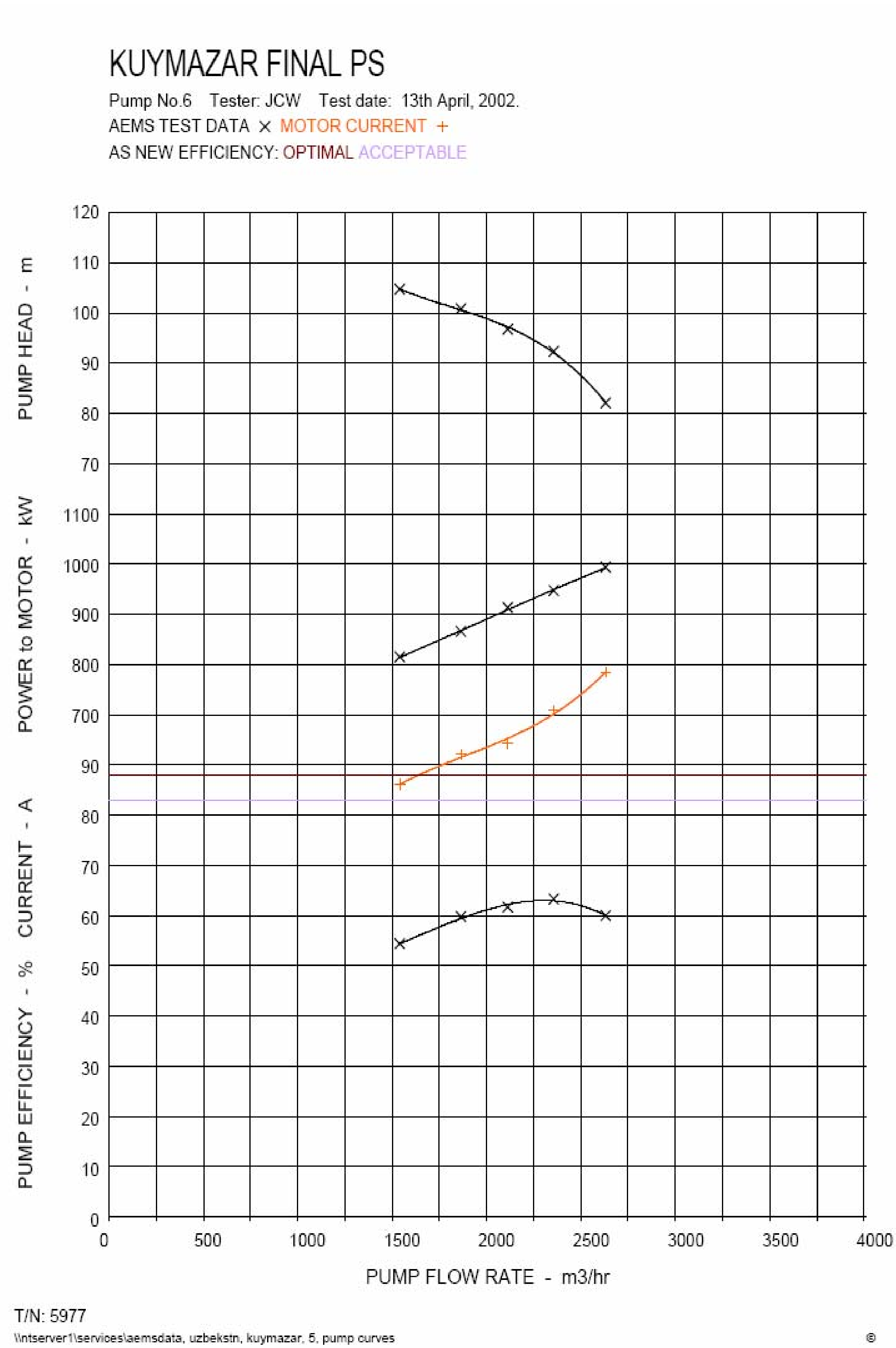
Bukhara

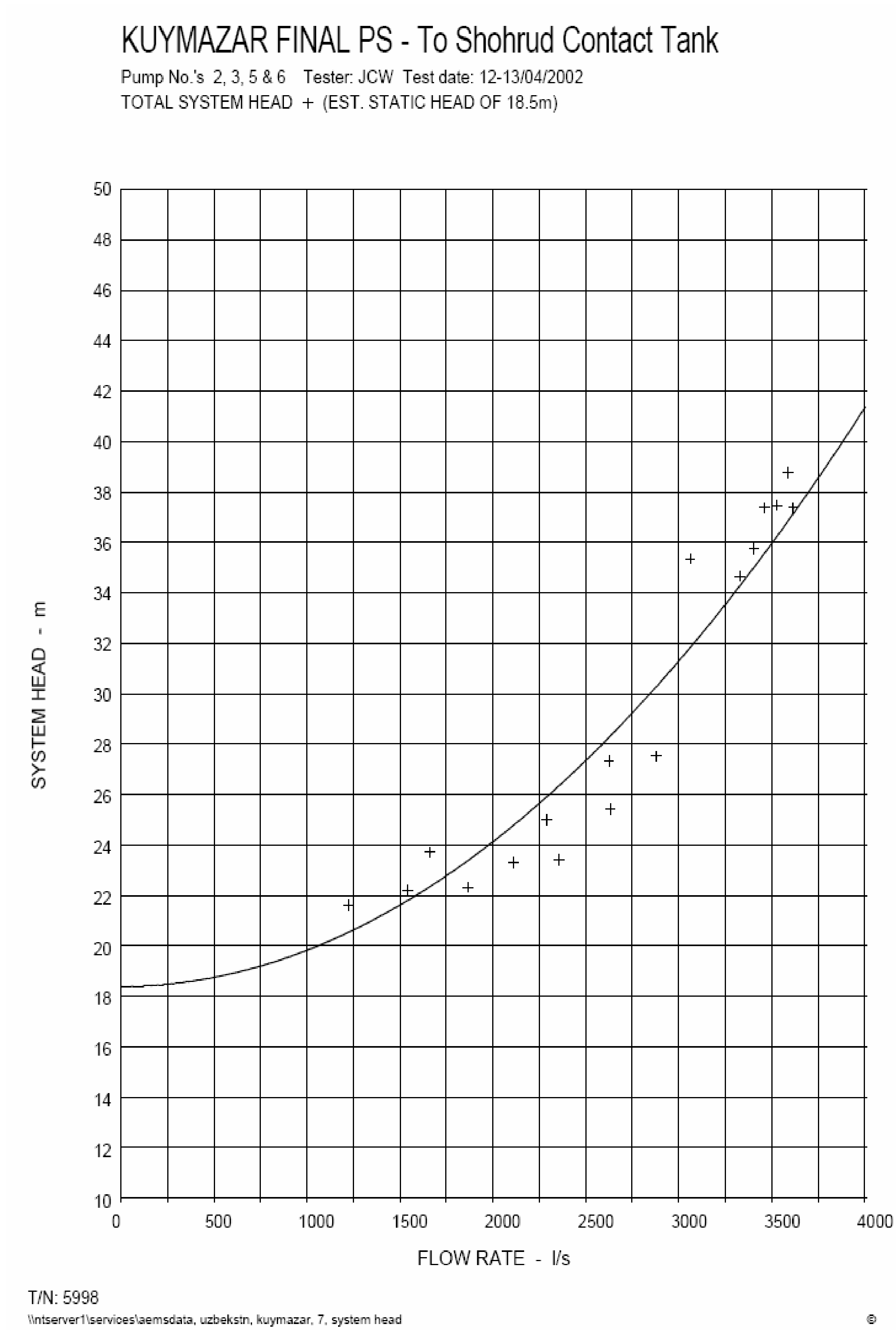
Ku Mazar Pump-sets: Pump curves 2, 3, 5, 6 & system curve



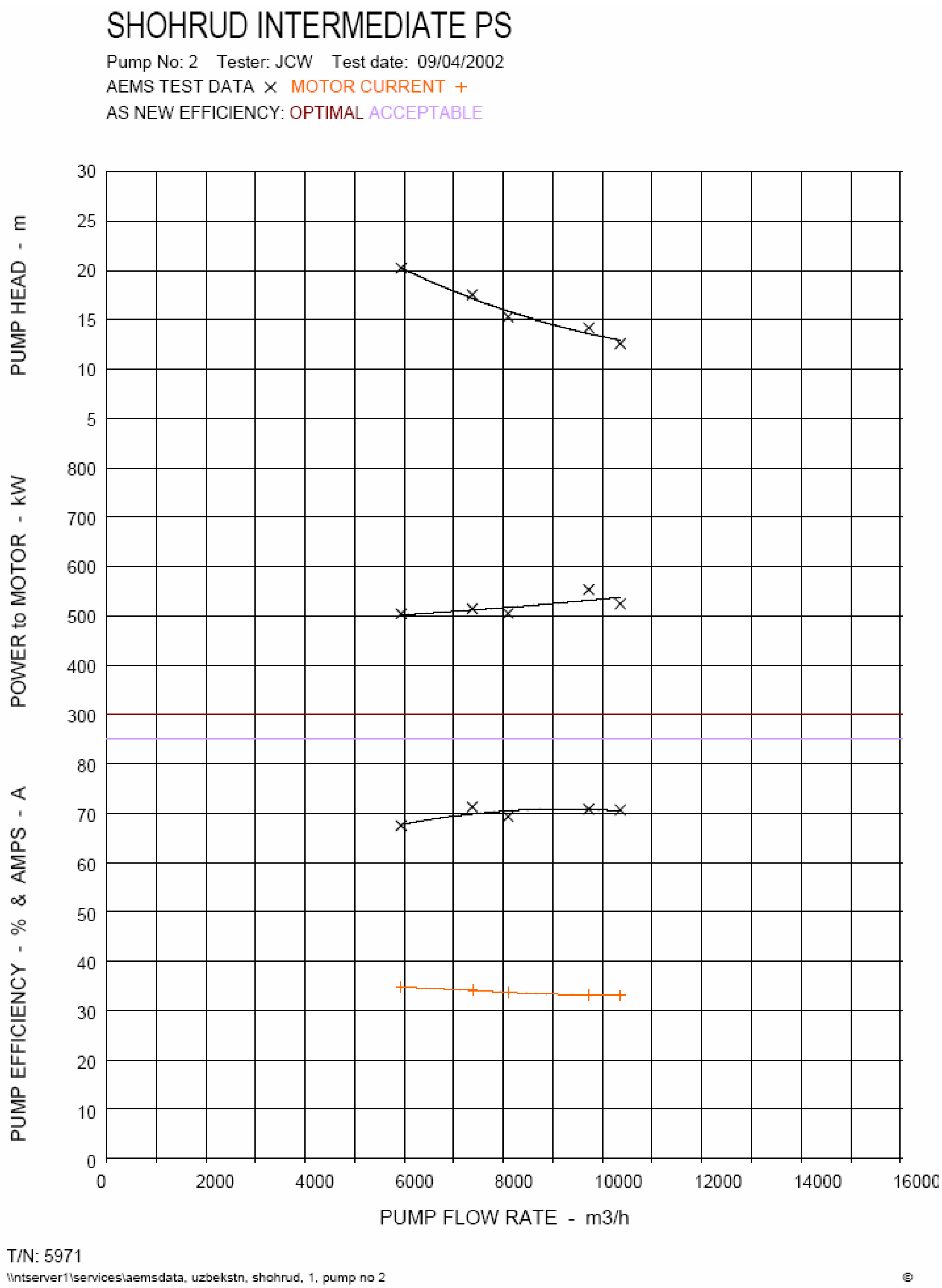

KUYMAZAR FINAL PS
Pump No.3 Tester: JCW Test date: 13th April, 2002.
AEMS TEST DATA × MOTOR CURRENT +
AS NEW EFFICIENCY: OPTIMAL ACCEPTABLE
PUMP HEAD - m
POWER to MOTOR - kW
PUMP EFFICIENCY - % CURRENT - A
80
70
60
50
40
30
550
500
450
400
90
80
70
60
50
40
30
20
10
0
0
500
1000
1500
2000
2500
3000
3500
4000
PUMP FLOW RATE - m3/hr
T/N: 5980
\\ntserver1\services\aemsdata, uzbekstn, kuymazar, 8, pump curves

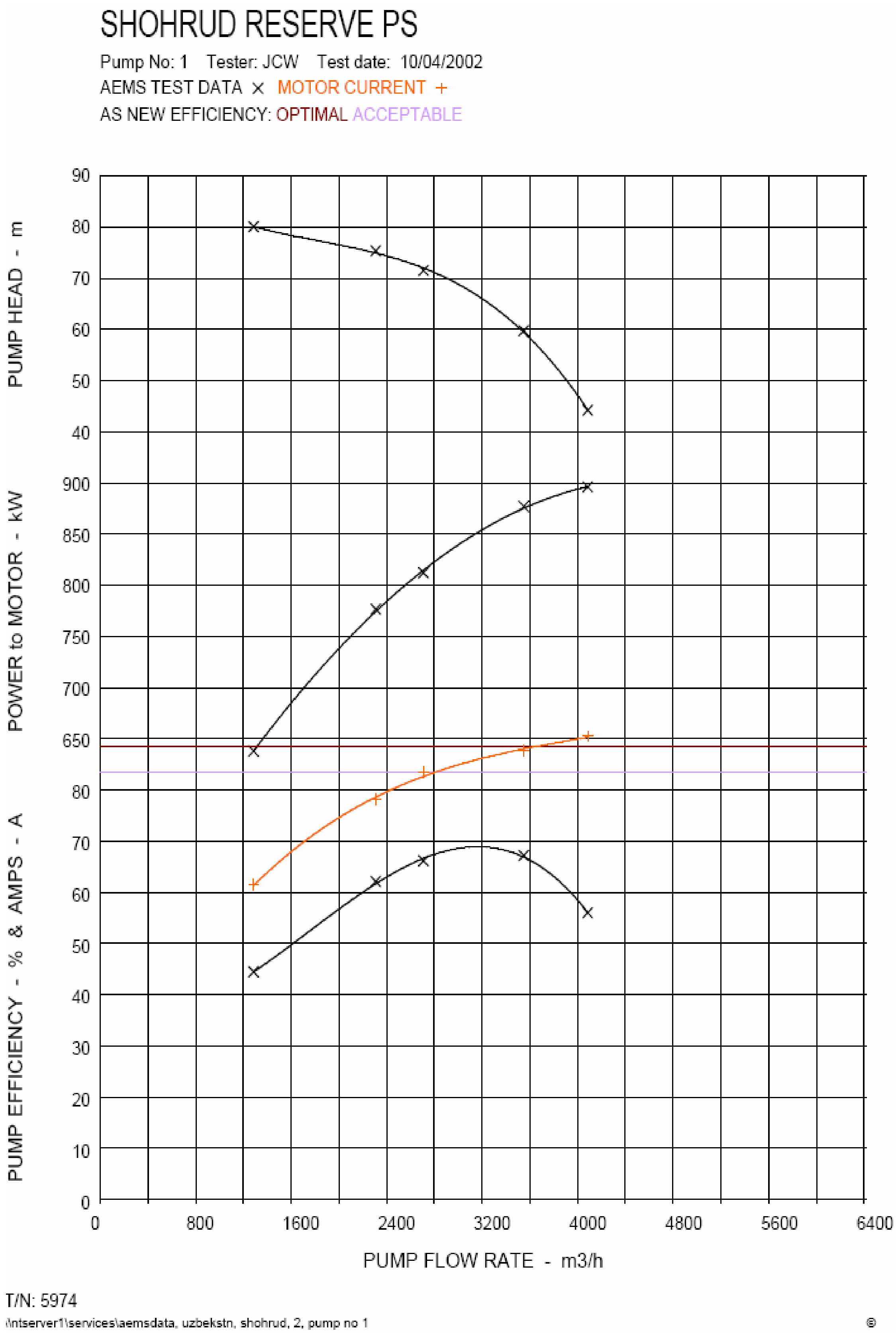

KUYMAZAR FINAL PS
Pump No.5 Tester: JCW Test date: 13th April, 2002.
AEMS TEST DATA × MOTOR CURRENT +
AS NEW EFFICIENCY: OPTIMAL ACCEPTABLE
PUMP HEAD - m
POWER to MOTOR - kW
PUMP EFFICIENCY - % CURRENT - A
90
80
70
60
50
40
800
700
600
500
400
90
80
70
60
50
40
30
20
10
0
0
500
1000
1500
2000
2500
3000
3500
4000
PUMP FLOW RATE - m3/hr
T/N: 5978
\\ntserver1\services\aemsdata, uzbekstn, kuymazar, 6, pump curves

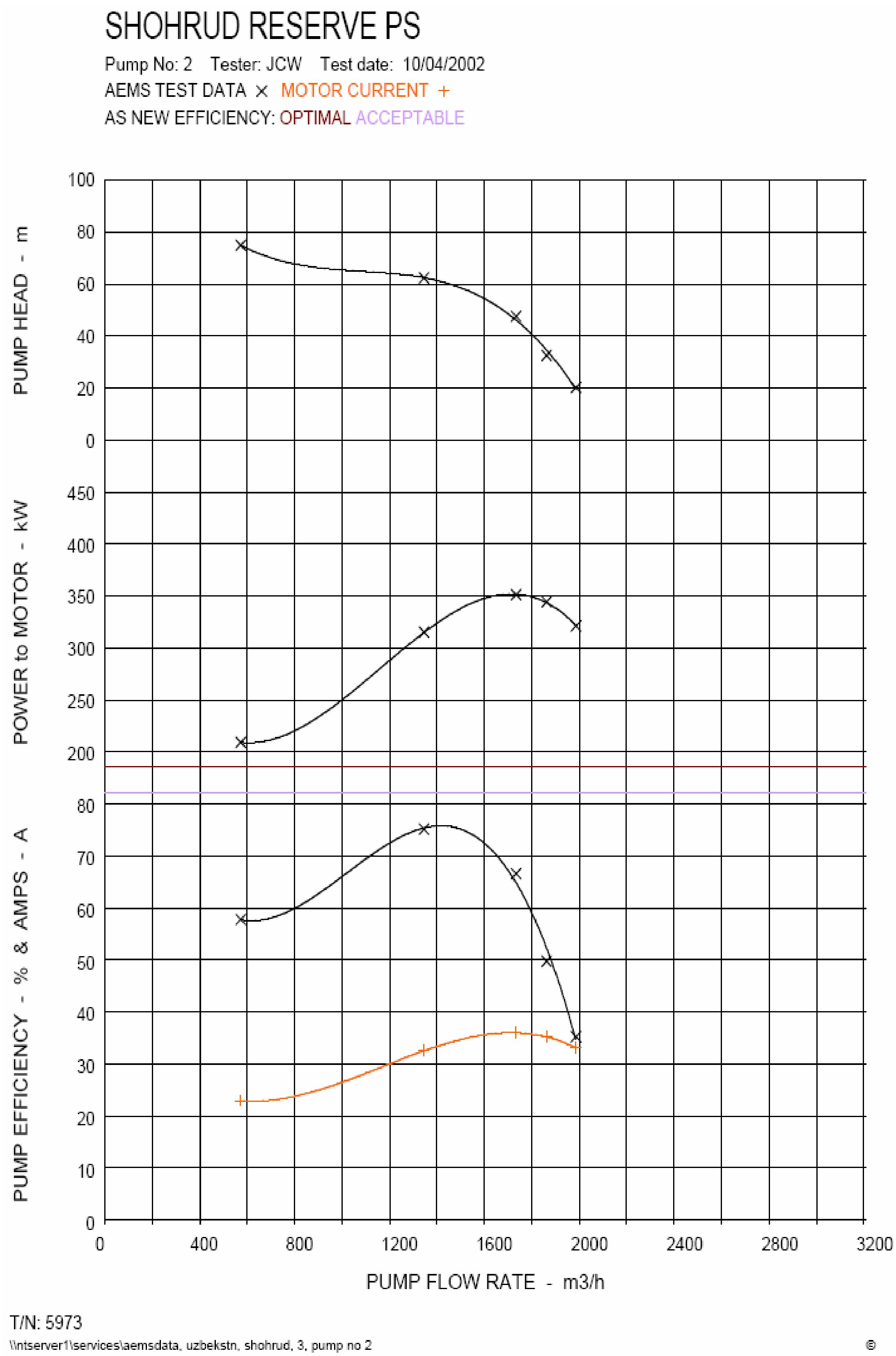

KUYMAZAR FINAL PS
Pump No.6 Tester: JCW Test date: 13th April, 2002.
AEMS TEST DATA × MOTOR CURRENT +
AS NEW EFFICIENCY: OPTIMAL ACCEPTABLE
PUMP HEAD - m
POWER to MOTOR - kW
PUMP EFFICIENCY - % CURRENT - A
PUMP FLOW RATE - m3/hr
120
110
100
90
80
70
1100
1000
900
800
700
90
80
70
60
50
40
30
20
10
0
0
500
1000
1500
2000
2500
3000
3500
4000
T/N: 5977
\\ntserver1\services\aemsdata, uzbekstn, kuymazar, 5, pump curves
©

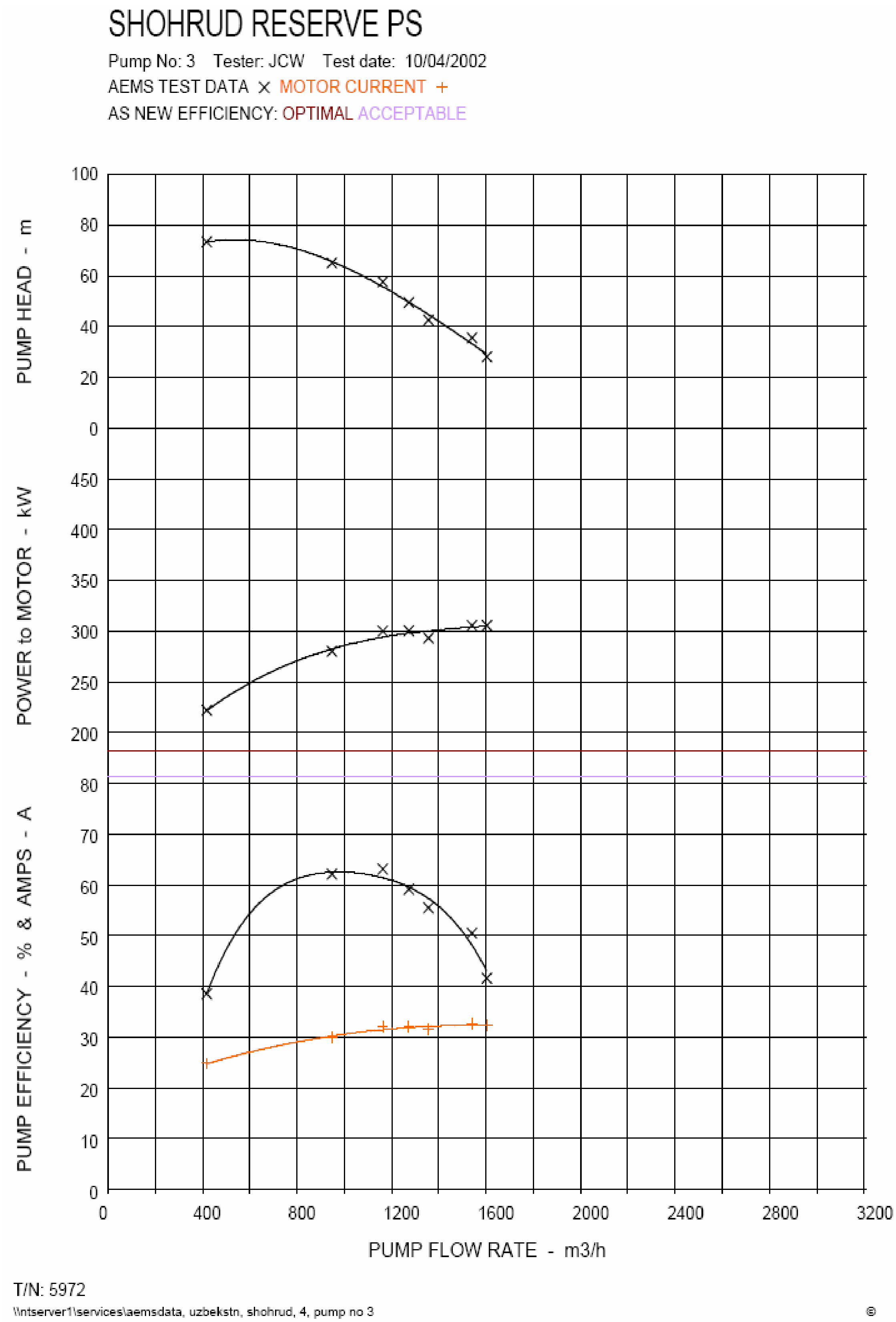

KUYMAZAR FINAL PS - To Shohrud Contact Tank
Pump No.'s 2, 3, 5 & 6 Tester: JCW Test date: 12-13/04/2002
TOTAL SYSTEM HEAD + (EST. STATIC HEAD OF 18.5m)
SYSTEM HEAD - m
FLOW RATE - l/s
50
48
46
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
0
500
1000
1500
2000
2500
3000
3500
4000
T/N: 5998
\\ntserver1\services\aemsdata, uzbekstn, kuymazar, 7, system head
©

Shohkrud Intermediate Pump-sets: Pump curves intermediate 2; reserve 1, 2, 3; & system curve




SHOHRUD RESERVE PS
Pump No: 1 Tester: JCW Test date: 10/04/2002
AEMS TEST DATA × MOTOR CURRENT +
AS NEW EFFICIENCY: OPTIMAL ACCEPTABLE
PUMP HEAD - m
POWER to MOTOR - kW
PUMP EFFICIENCY - % & AMPS - A
PUMP FLOW RATE - m3/h
90
80
70
60
50
40
900
850
800
750
700
650
80
70
60
50
40
30
20
10
0
0
800
1600
2400
3200
4000
4800
5600
6400
T/N: 5974
\\ntserver1\services\aemsdata, uzbekstn, shohrud, 2, pump no 1
©

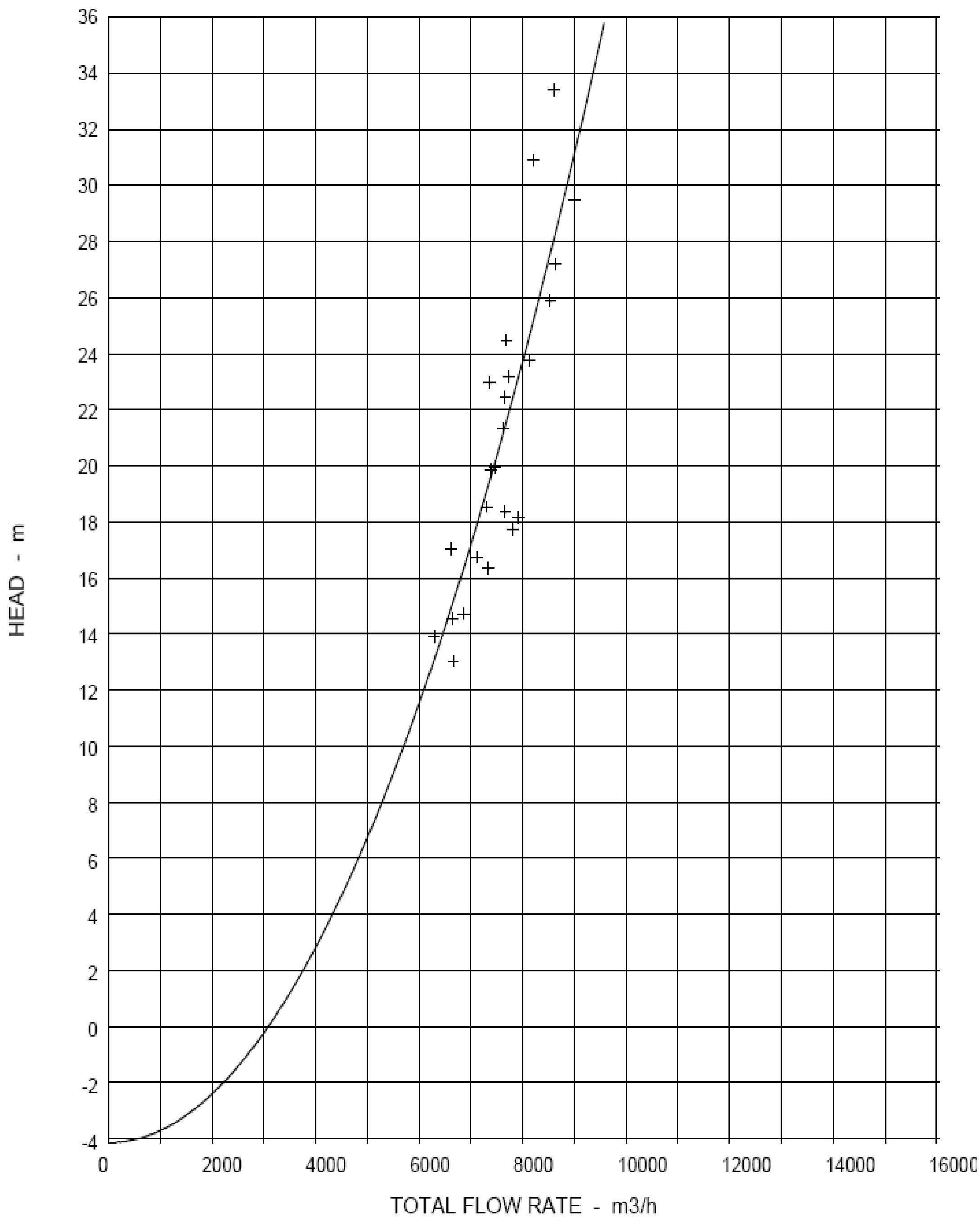

SHOHRUD RESERVE PS
Pump No: 2 Tester: JCW Test date: 10/04/2002
AEMS TEST DATA × MOTOR CURRENT +
AS NEW EFFICIENCY: OPTIMAL ACCEPTABLE
PUMP HEAD - m
100
80
60
40
20
0
POWER to MOTOR - kW
450
400
350
300
250
200
PUMP EFFICIENCY - % & AMPS - A
80
70
60
50
40
30
20
10
0
0
400
800
1200
1600
2000
2400
2800
3200
PUMP FLOW RATE - m3/h
T/N: 5973
\\ntserver1\services\aemsdata, uzbekstn, shohrud, 3, pump no 2
©


SHOHRUD RESERVE PS
Pump No: 3 Tester: JCW Test date: 10/04/2002
AEMS TEST DATA × MOTOR CURRENT +
AS NEW EFFICIENCY: OPTIMAL ACCEPTABLE
PUMP HEAD - m
POWER to MOTOR - kW
PUMP EFFICIENCY - % & AMPS - A
100
80
60
40
20
0
450
400
350
300
250
200
80
70
60
50
40
30
20
10
0
0
400
800
1200
1600
2000
2400
2800
3200
PUMP FLOW RATE - m3/h
T/N: 5972
\\ntserver1\services\aemsdata, uzbekstn, shohrud, 4, pump no 3
©

SHOHRUD FINAL & RESERVE PS - To Bukhara Distribution

Pump No.'s 1, 2, 3, 5 & 7 Tester: JCW Test date: 10-11/04/2002

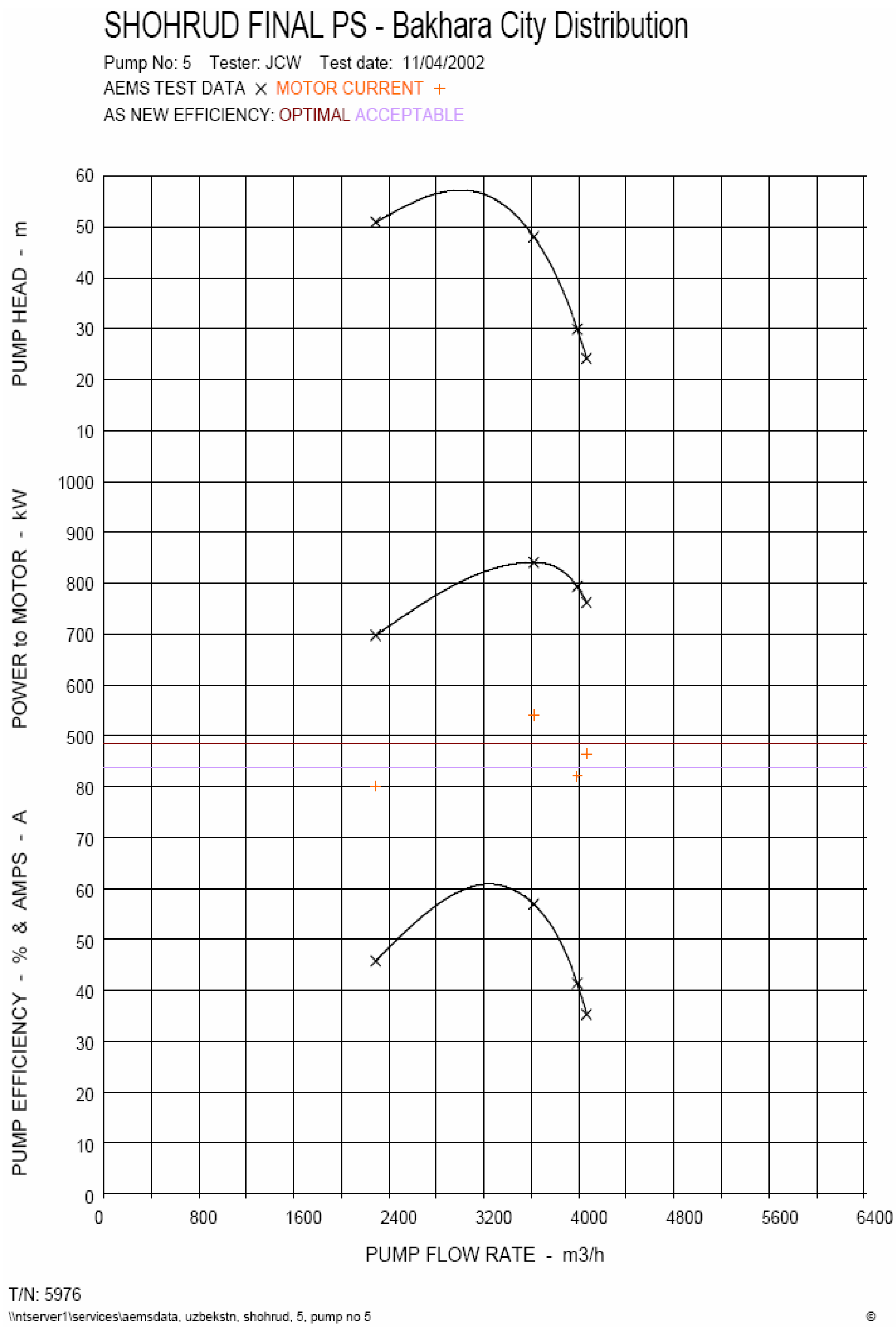
TOTAL SYSTEM HEAD + (EST. STATIC HEAD OF -4 m)



T/N: 5997

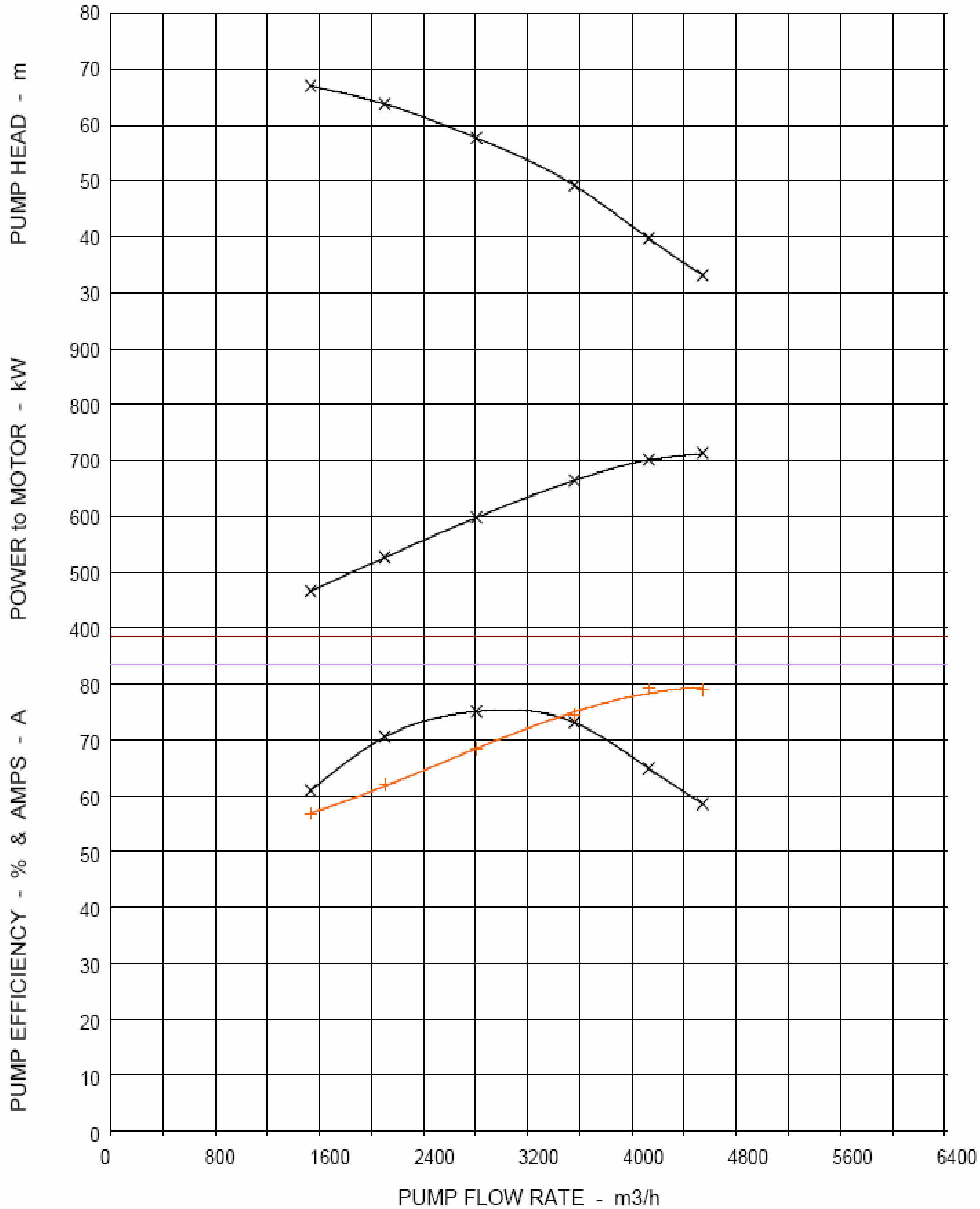
\\ntserver1\services\aemsdata, uzbekstn, shohrud, 2, system head ©

Shohkrud Final Pump-sets: Pump curves 5, 7



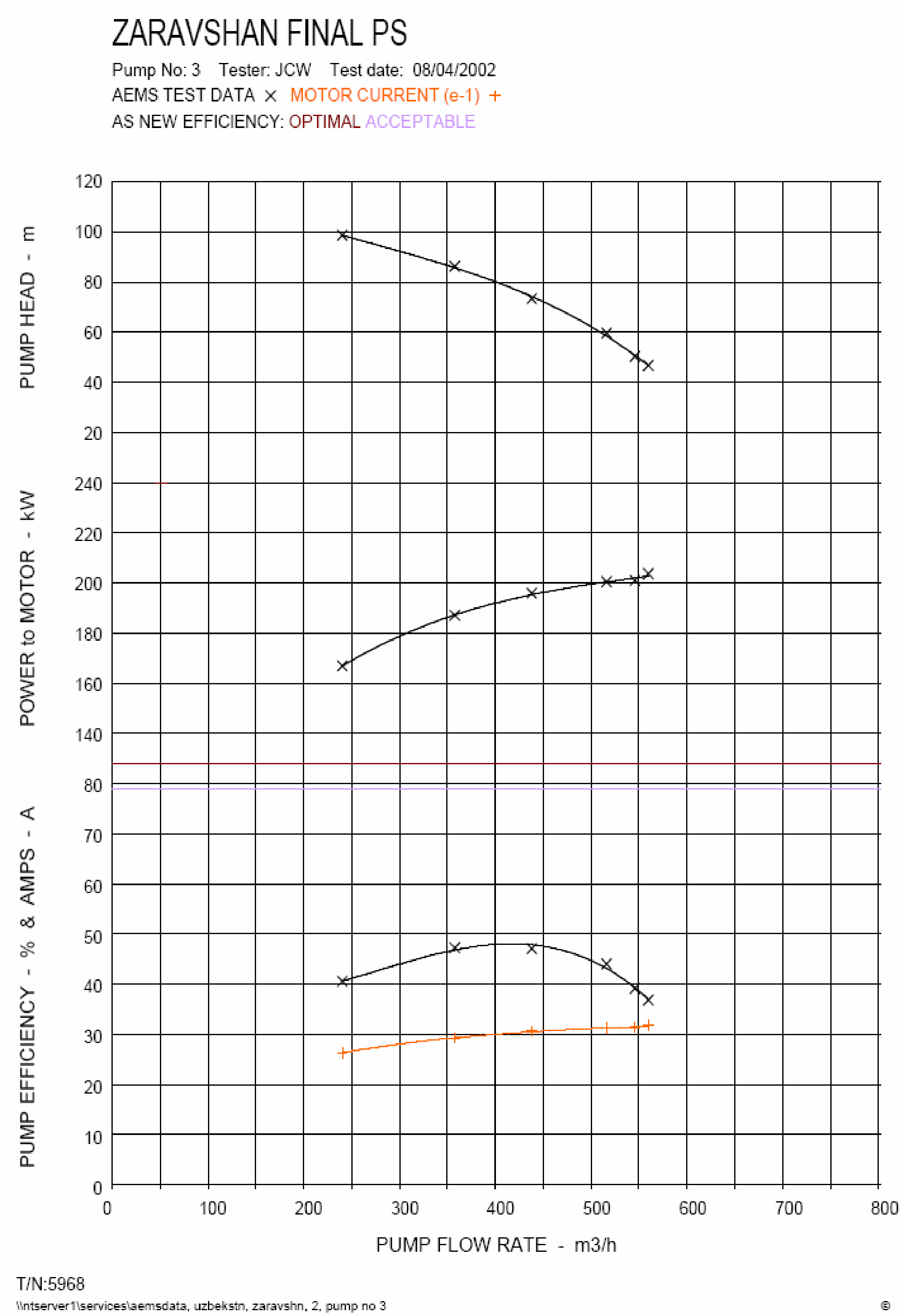
SHOHRUD FINAL PS

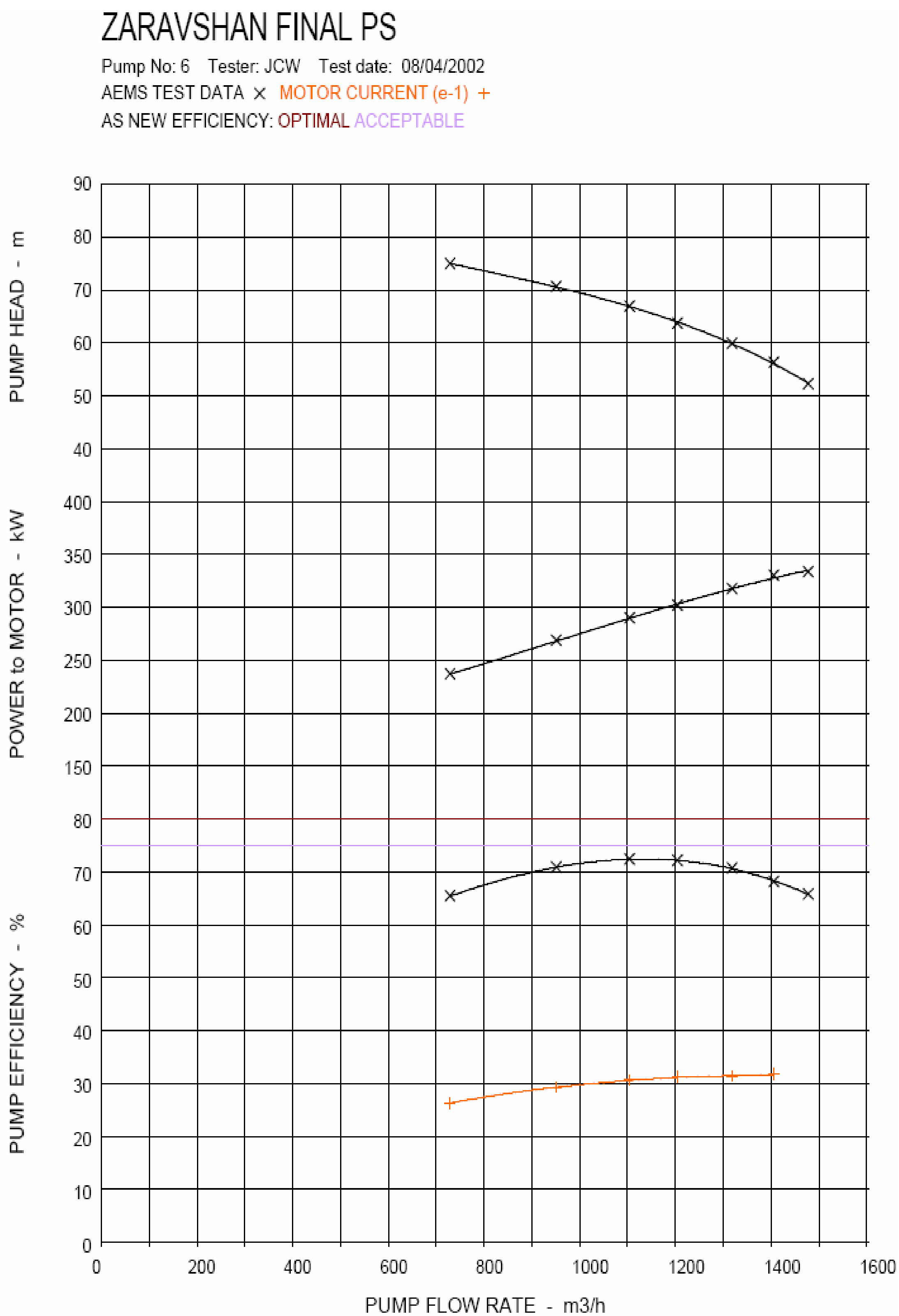
Pump No: 7 Tester: JCW Test date: 11/04/2002
AEMS TEST DATA × MOTOR CURRENT +
AS NEW EFFICIENCY: OPTIMAL ACCEPTABLE



T/N: 5975
\\ntserver1\services\aemsdata, uzbekstn, shohrud, 6, pump no 7 ©

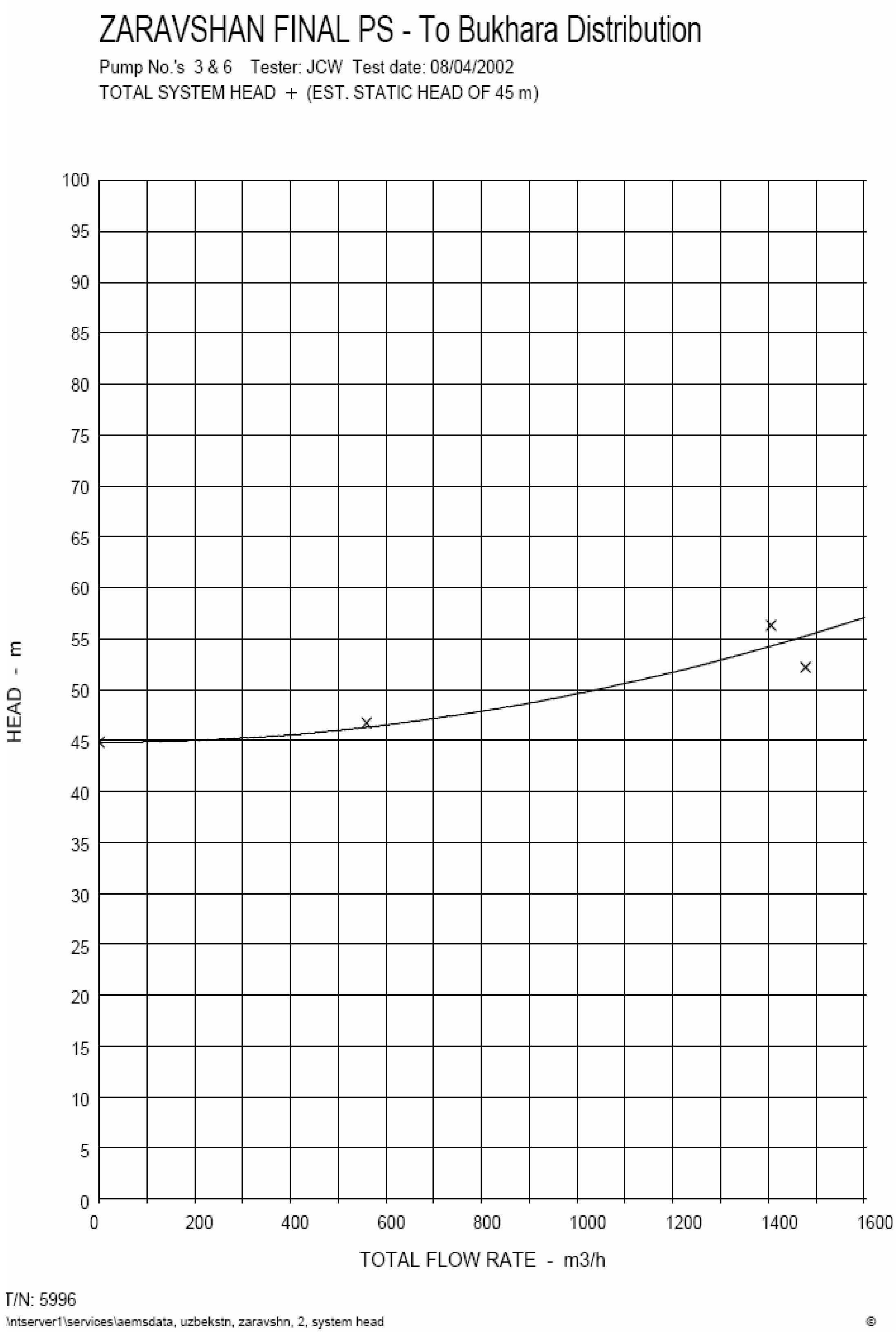
Zaravshan Final Pump-sets: Pump curves 3, 6; & system curve



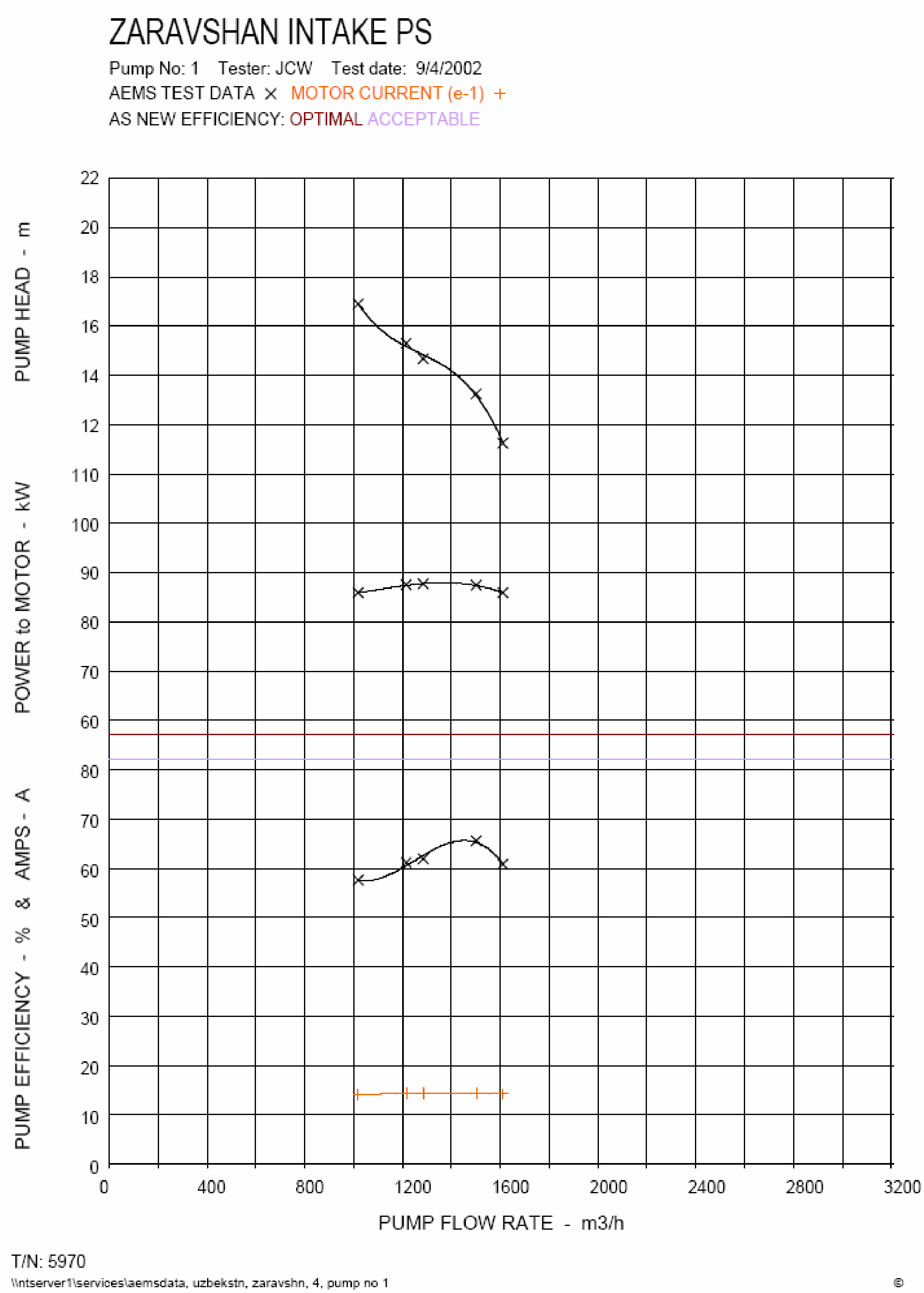


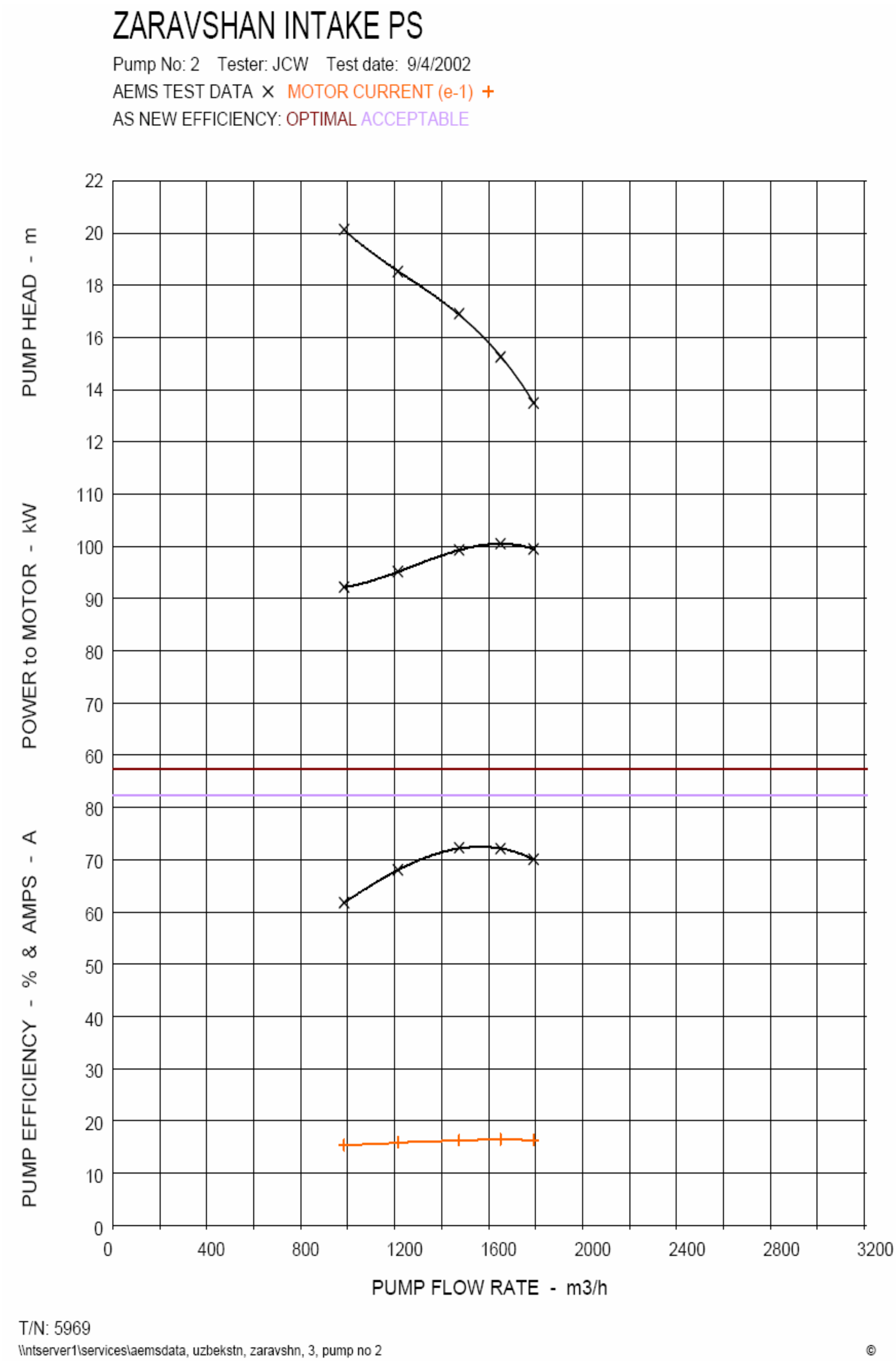
T/N: 5967

\\ntserver1\services\aemsdata, uzbekstn, zaravshn, 1, pump no 6 ©


ZARAVSHAN FINAL PS - To Bukhara Distribution
Pump No.'s 3 & 6 Tester: JCW Test date: 08/04/2002
TOTAL SYSTEM HEAD + (EST. STATIC HEAD OF 45 m)
HEAD - m
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0
200
400
600
800
1000
1200
1400
1600
TOTAL FLOW RATE - m3/h
T/N: 5996
\ntserver1\services\aemsdata, uzbekstn, zaravshn, 2, system head
©

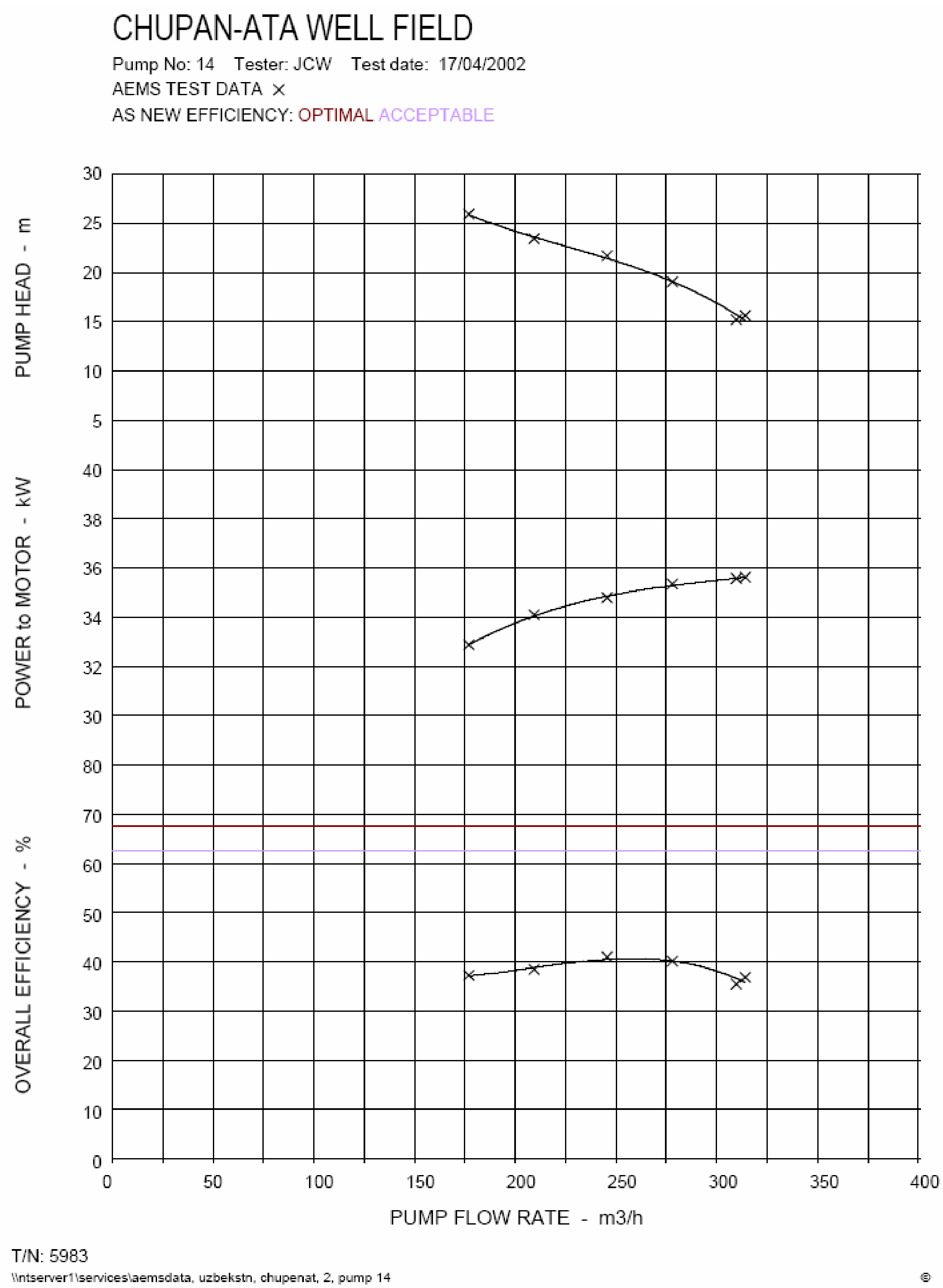
Zaravshan Intake Pump-sets: Pump curves 1, 2

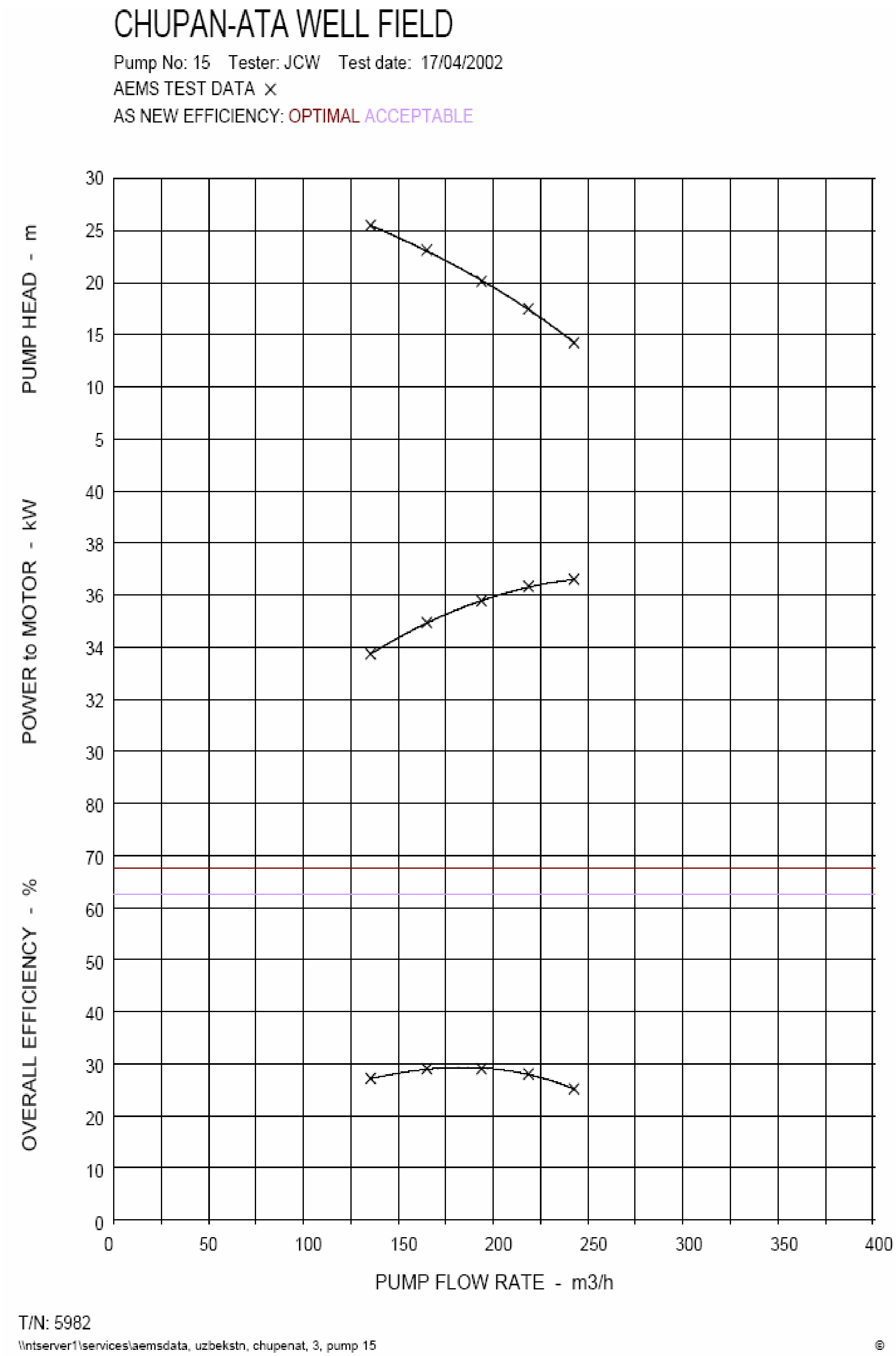



ZARAVSHAN INTAKE PS
Pump No: 2 Tester: JCW Test date: 9/4/2002
AEMS TEST DATA × MOTOR CURRENT (e-1) +
AS NEW EFFICIENCY: OPTIMAL ACCEPTABLE
PUMP HEAD - m
POWER to MOTOR - kW
PUMP EFFICIENCY - % & AMPS - A
22
20
18
16
14
12
110
100
90
80
70
60
80
70
60
50
40
30
20
10
0
0
400
800
1200
1600
2000
2400
2800
3200
PUMP FLOW RATE - m3/h
T/N: 5969
\\ntserver1\services\aemsdata, uzbekstn, zaravshn, 3, pump no 2
©

Samarkand

Chuponata Well Field Pump-sets: Pump curves 14, 15, and 17



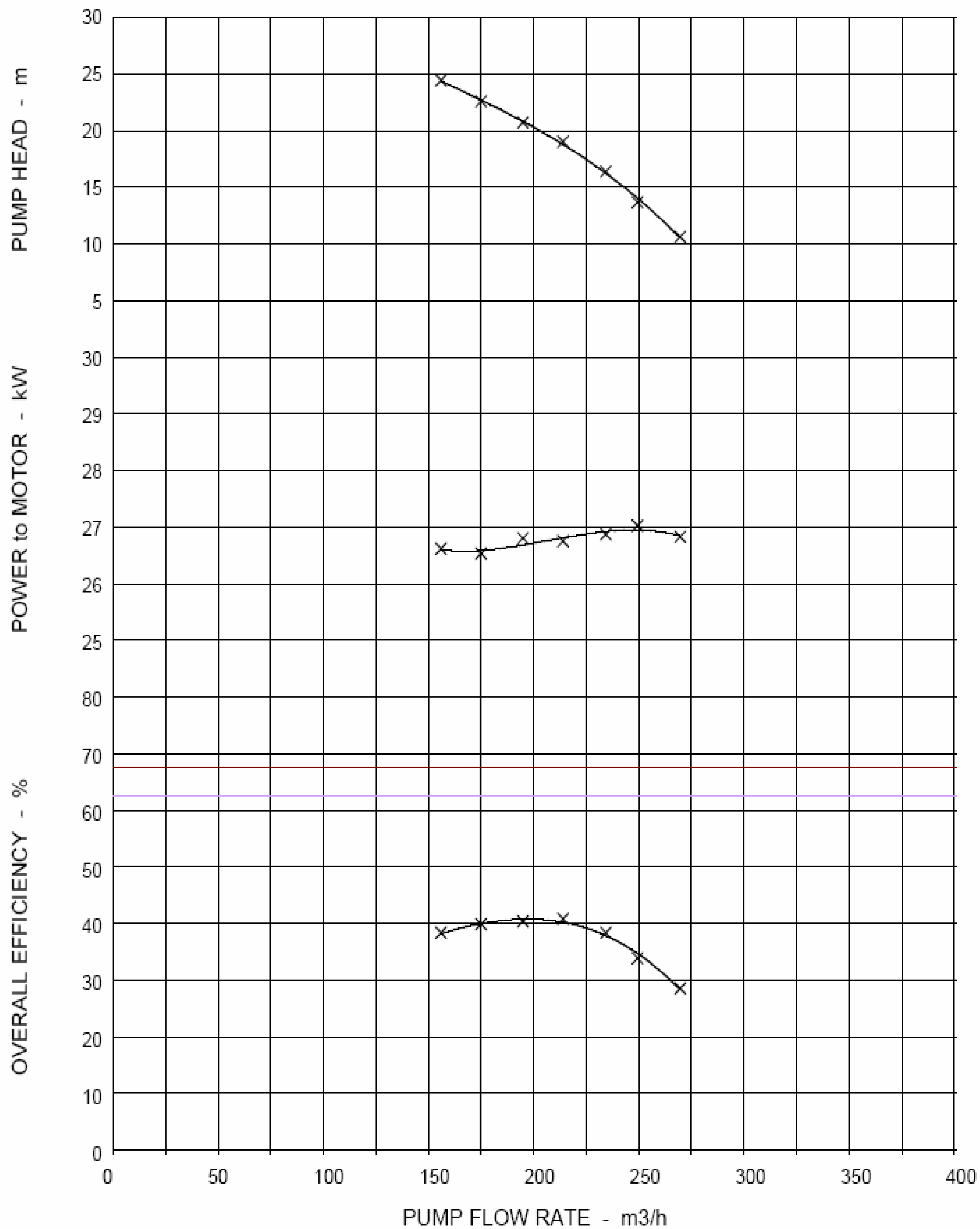

CHUPAN-ATA WELL FIELD
Pump No: 15 Tester: JCW Test date: 17/04/2002
AEMS TEST DATA ×
AS NEW EFFICIENCY: OPTIMAL ACCEPTABLE
PUMP HEAD - m
POWER to MOTOR - kW
OVERALL EFFICIENCY - %
PUMP FLOW RATE - m3/h
T/N: 5982
\\ntserver1\services\aemsdata, uzbekstn, chupenat, 3, pump 15

CHUPAN-ATA WELL FIELD

Pump No: 17 Tester: JCW Test date: 17/04/2002

AEMS TEST DATA ×

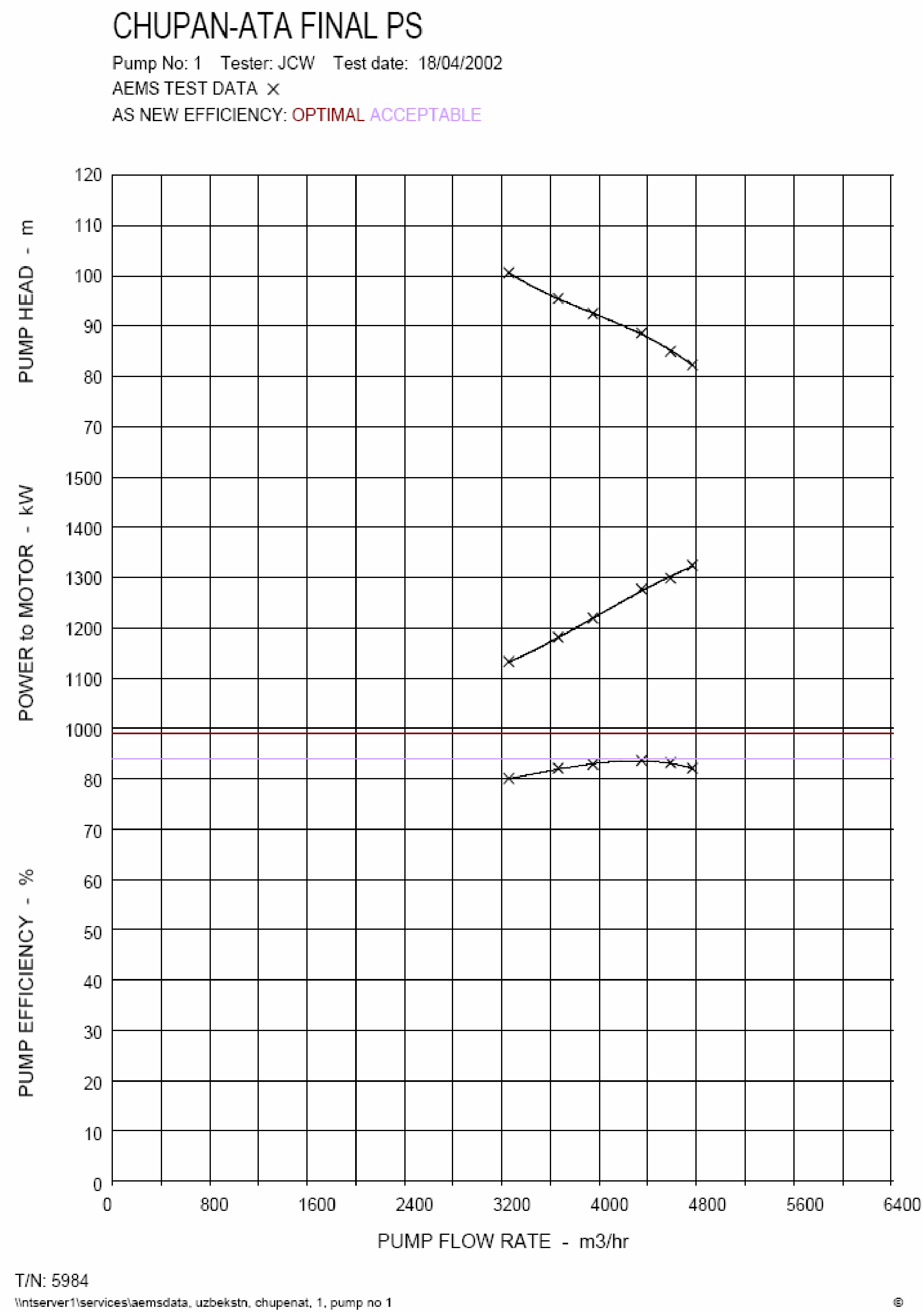
AS NEW EFFICIENCY: OPTIMAL ACCEPTABLE

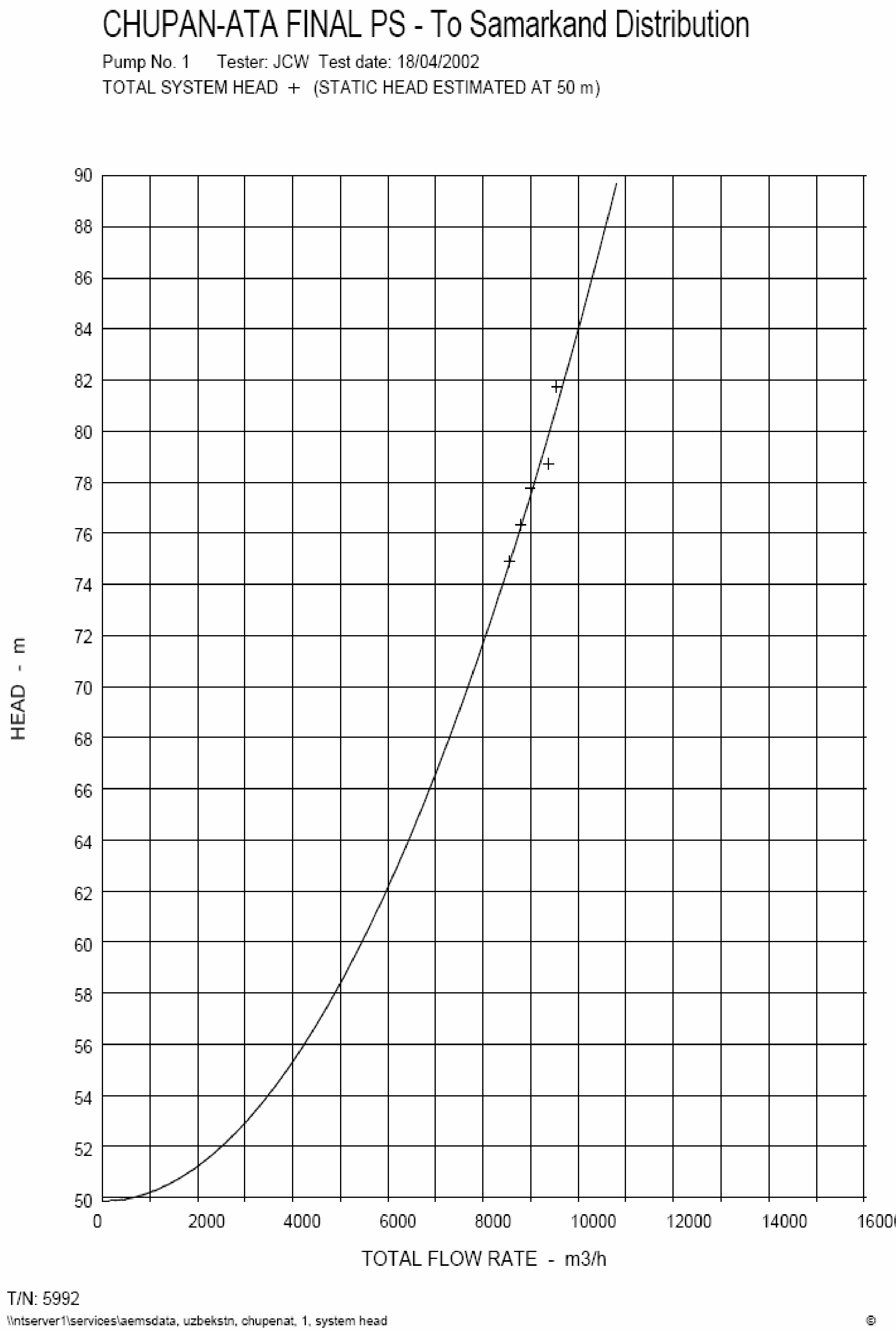


T/N: 5981

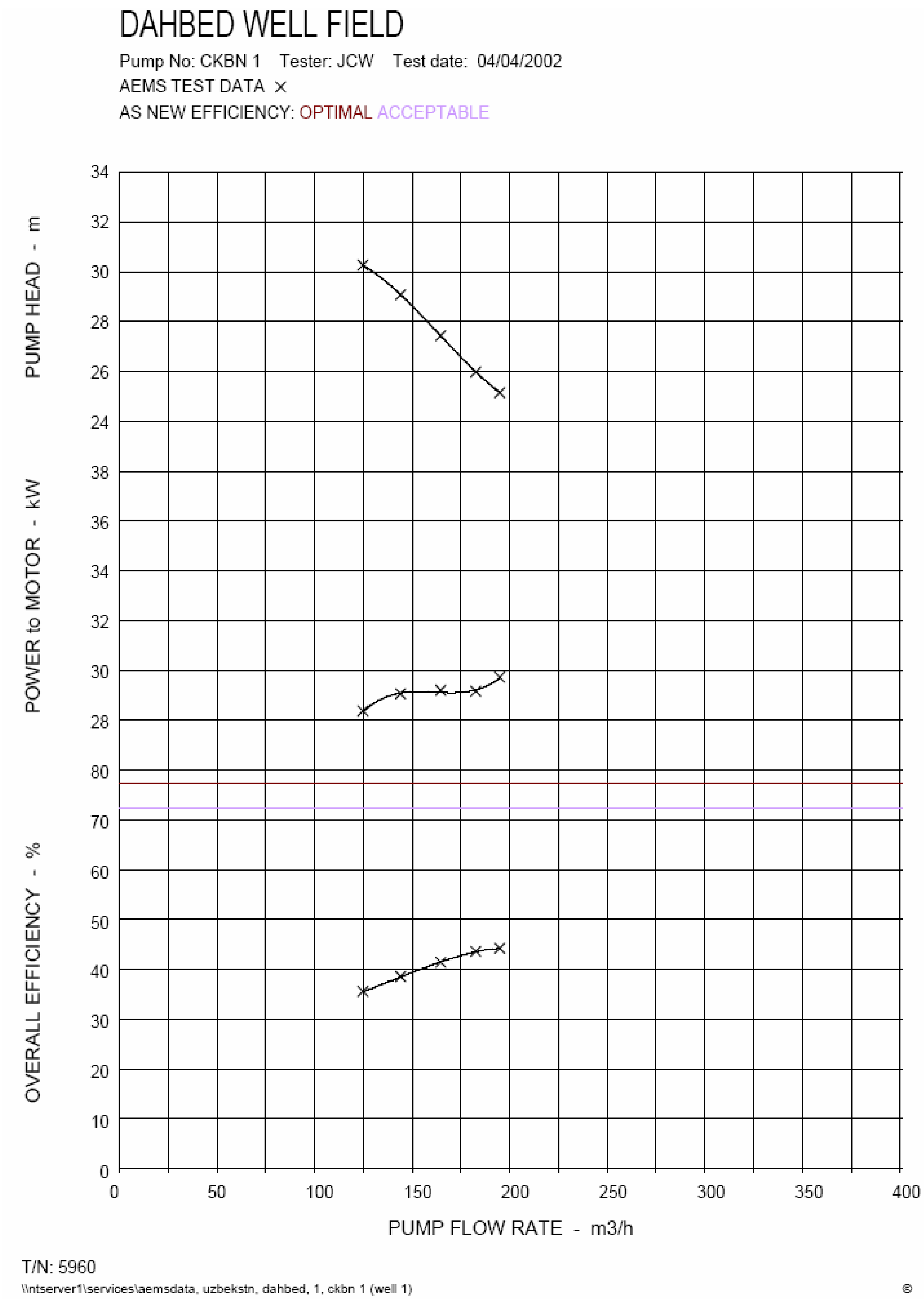
\\ntserver1\services\aemsdata, uzbekstn, chupenat, 4, pump 17

Chuponata Final Pump-sets: Pump curves 1, 2, 4; & system curve




CHUPAN-ATA FINAL PS - To Samarkand Distribution
Pump No. 1 Tester: JCW Test date: 18/04/2002
TOTAL SYSTEM HEAD + (STATIC HEAD ESTIMATED AT 50 m)
HEAD - m
90
88
86
84
82
80
78
76
74
72
70
68
66
64
62
60
58
56
54
52
50
0
2000
4000
6000
8000
10000
12000
14000
16000
TOTAL FLOW RATE - m3/h
T/N: 5992
\\ntserver1\services\aemsdata, uzbekstn, chupenat, 1, system head

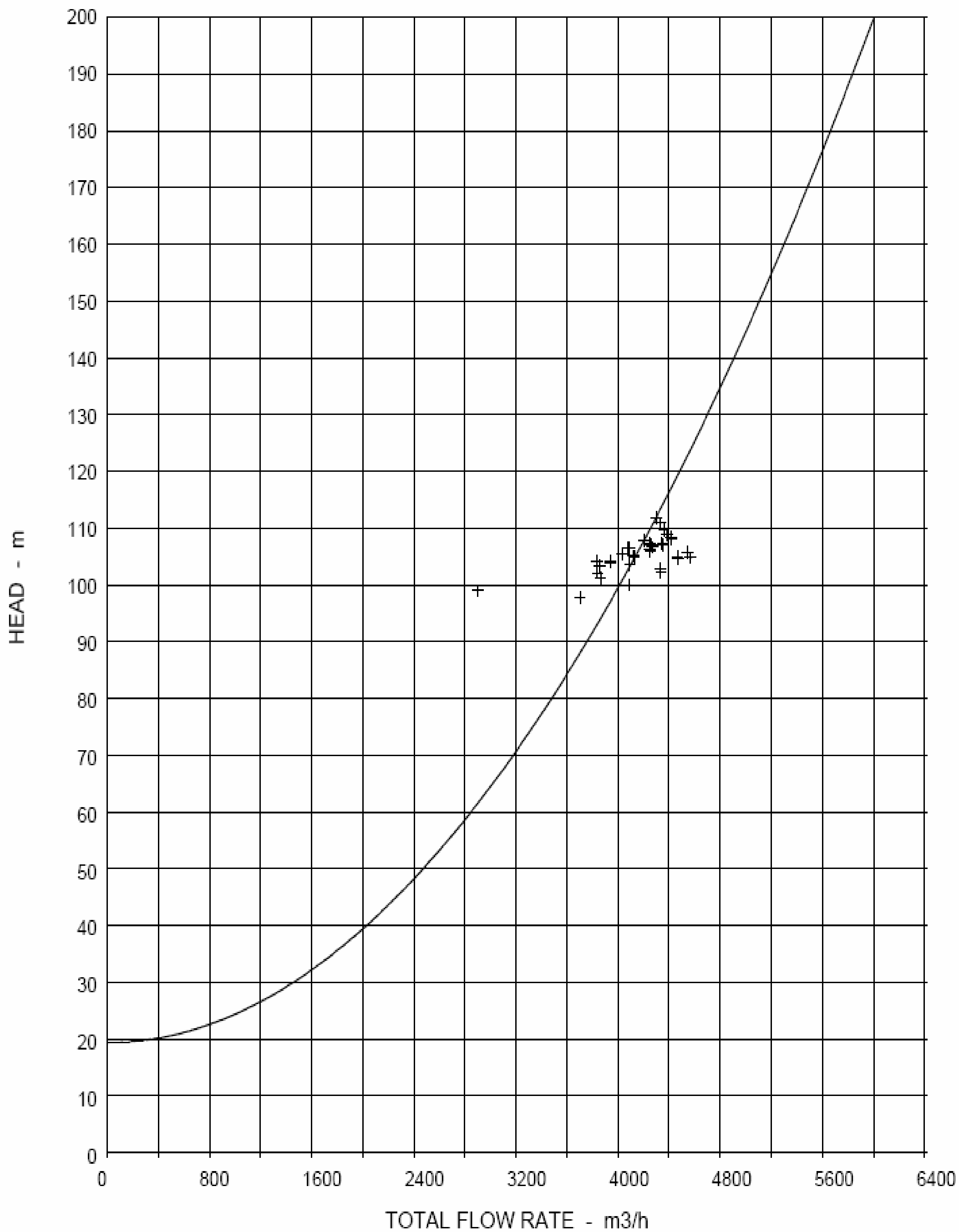
Dahbed Well Field Pump-sets: Pump curves 1; & system curve



DAHBED FINAL PS - To Samarkand Distribution

Pump No.'s 2, 3, 5 & 6 Tester: JCW Test date: 06/04/2002

TOTAL SYSTEM HEAD + (STATIC HEAD ESTIMATED AT 20 m)

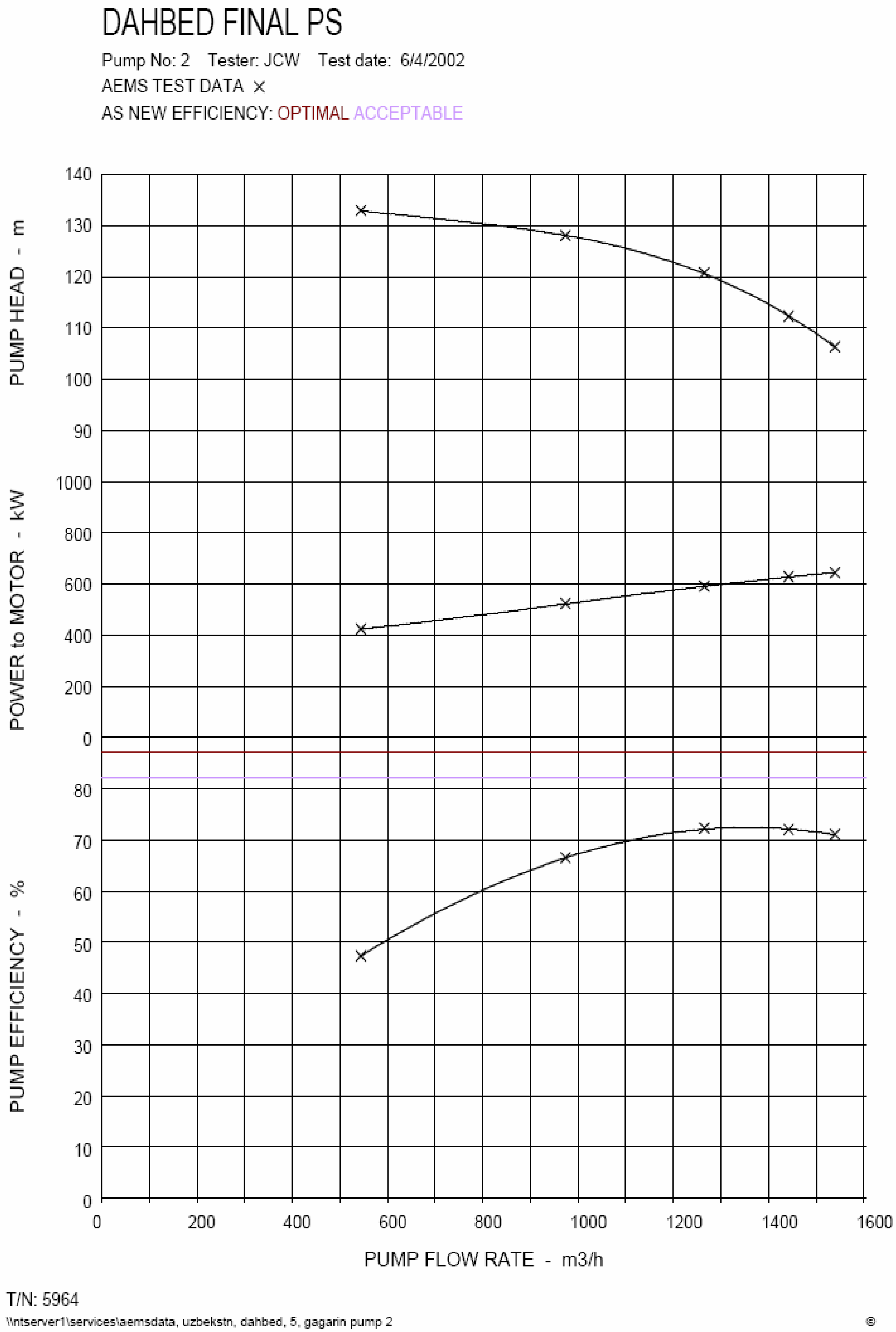


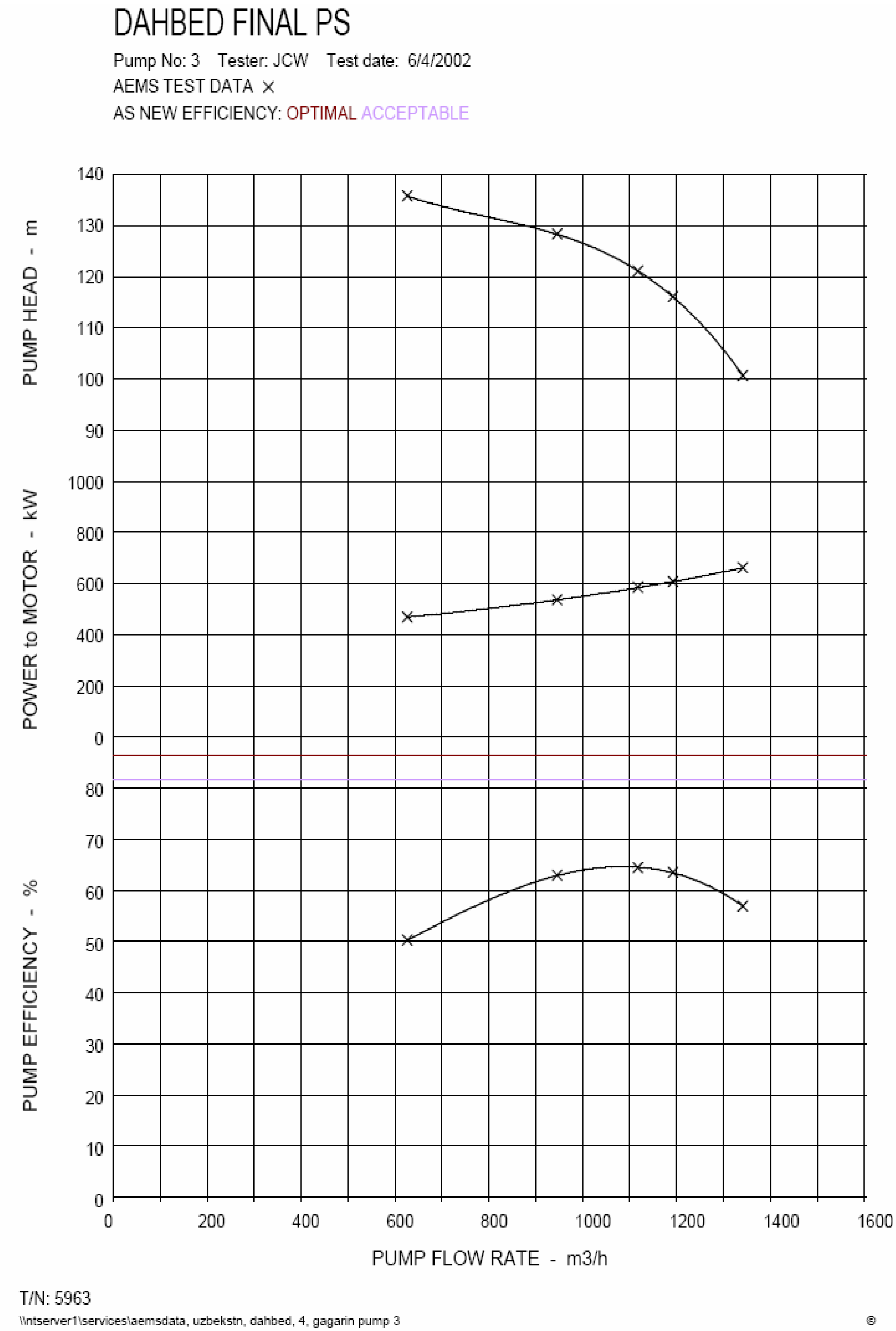
T/N: 5991

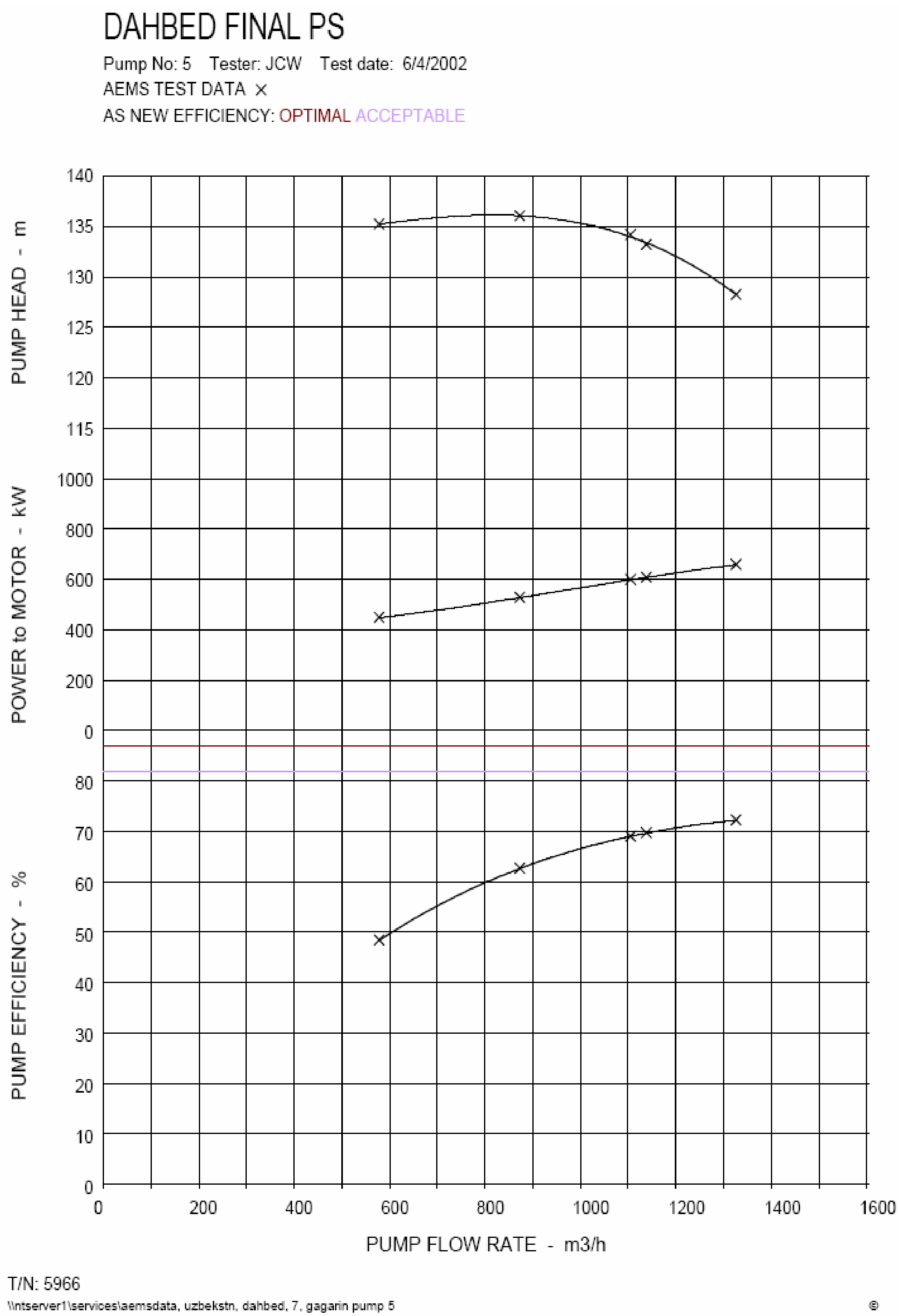
\\ntserver1\services\aemsdata, uzbekstn, dahbed, 5, system head

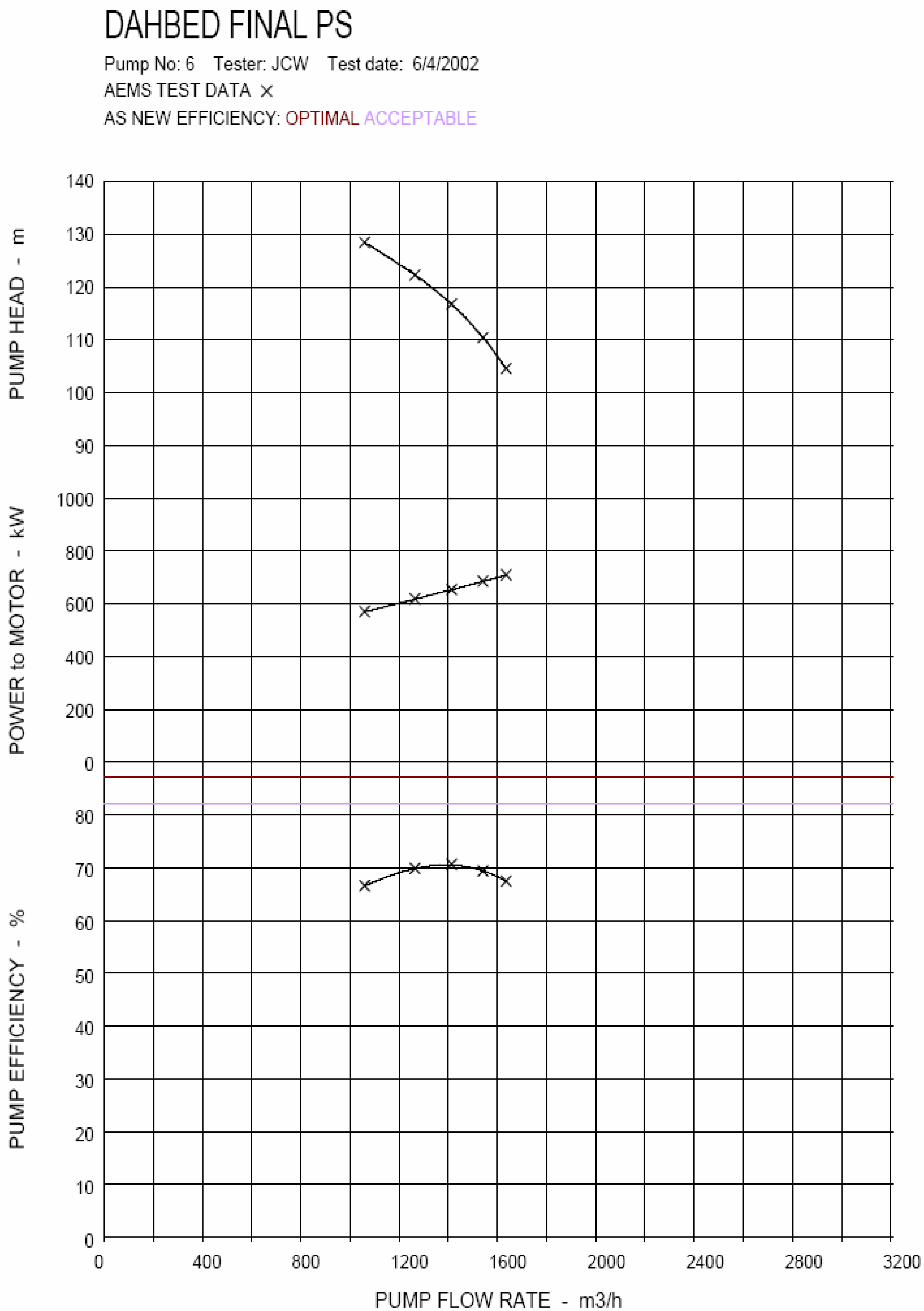
©

Dahbed Final Pump-sets: Pump curves 2, 3, 5 & 6




DAHBED FINAL PS
Pump No: 3 Tester: JCW Test date: 6/4/2002
AEMS TEST DATA ×
AS NEW EFFICIENCY: OPTIMAL ACCEPTABLE
PUMP HEAD - m
POWER to MOTOR - kW
PUMP EFFICIENCY - %
140
130
120
110
100
90
1000
800
600
400
200
0
80
70
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200
1400
1600
PUMP FLOW RATE - m3/h
T/N: 5963
\\ntserver1\services\aemsdata, uzbekstn, dahbed, 4, gagarin pump 3

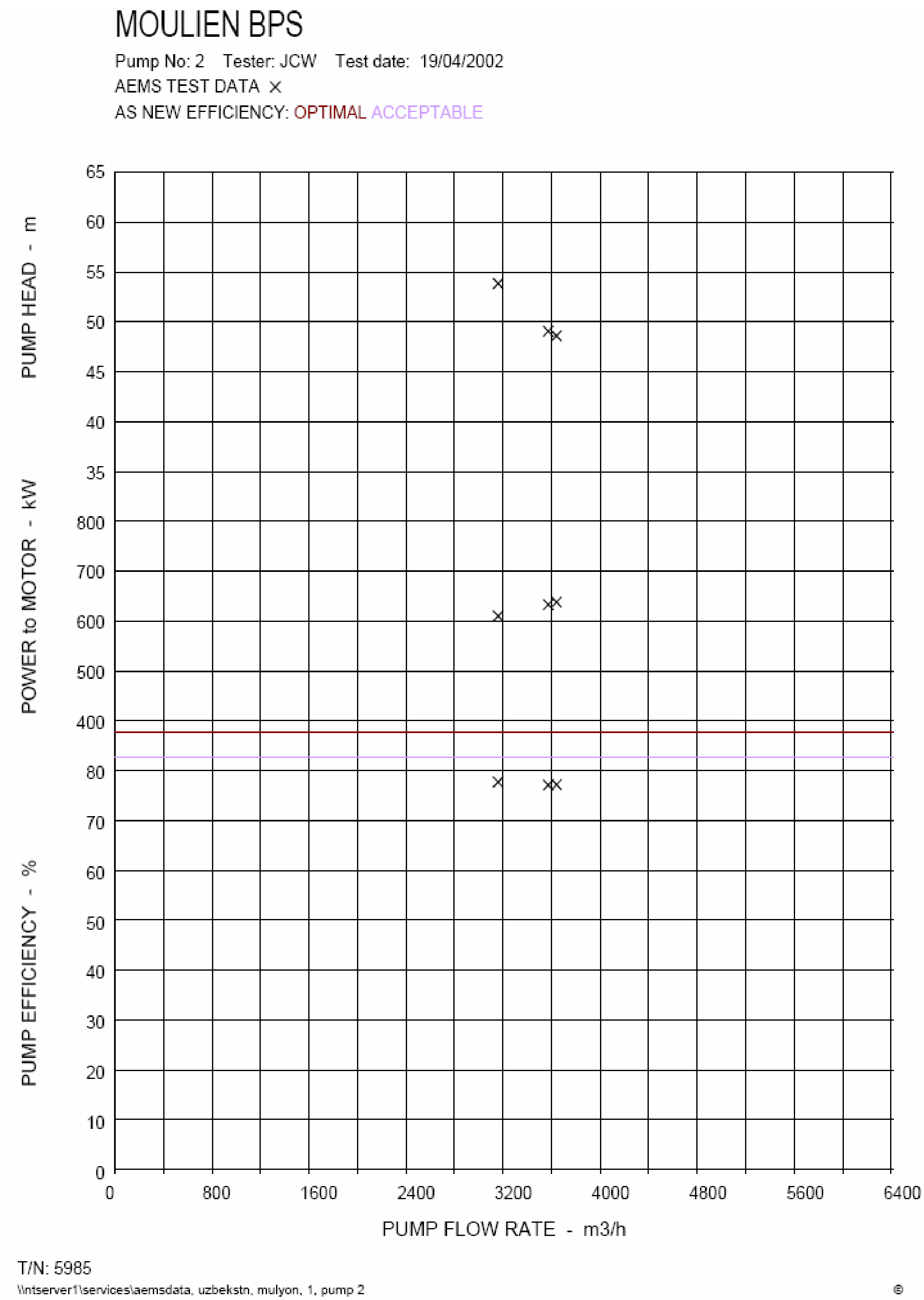

DAHBED FINAL PS
Pump No: 5 Tester: JCW Test date: 6/4/2002
AEMS TEST DATA ×
AS NEW EFFICIENCY: OPTIMAL ACCEPTABLE
PUMP HEAD - m
140
135
130
125
120
115
POWER to MOTOR - kW
1000
800
600
400
200
0
PUMP EFFICIENCY - %
80
70
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200
1400
1600
PUMP FLOW RATE - m3/h
T/N: 5966
\\ntserver1\services\aemsdata, uzbekstn, dahbed, 7, gagarin pump 5
©

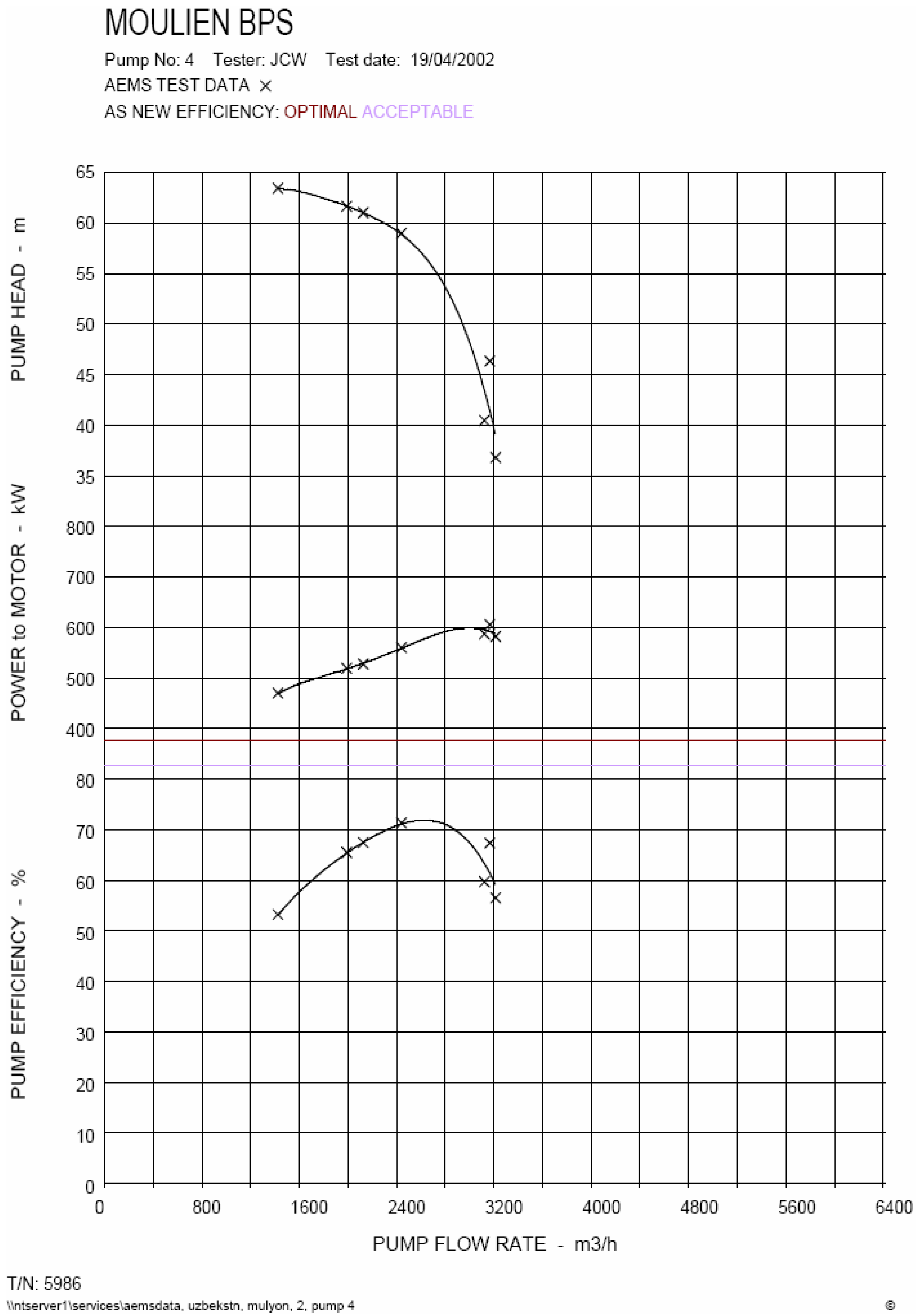


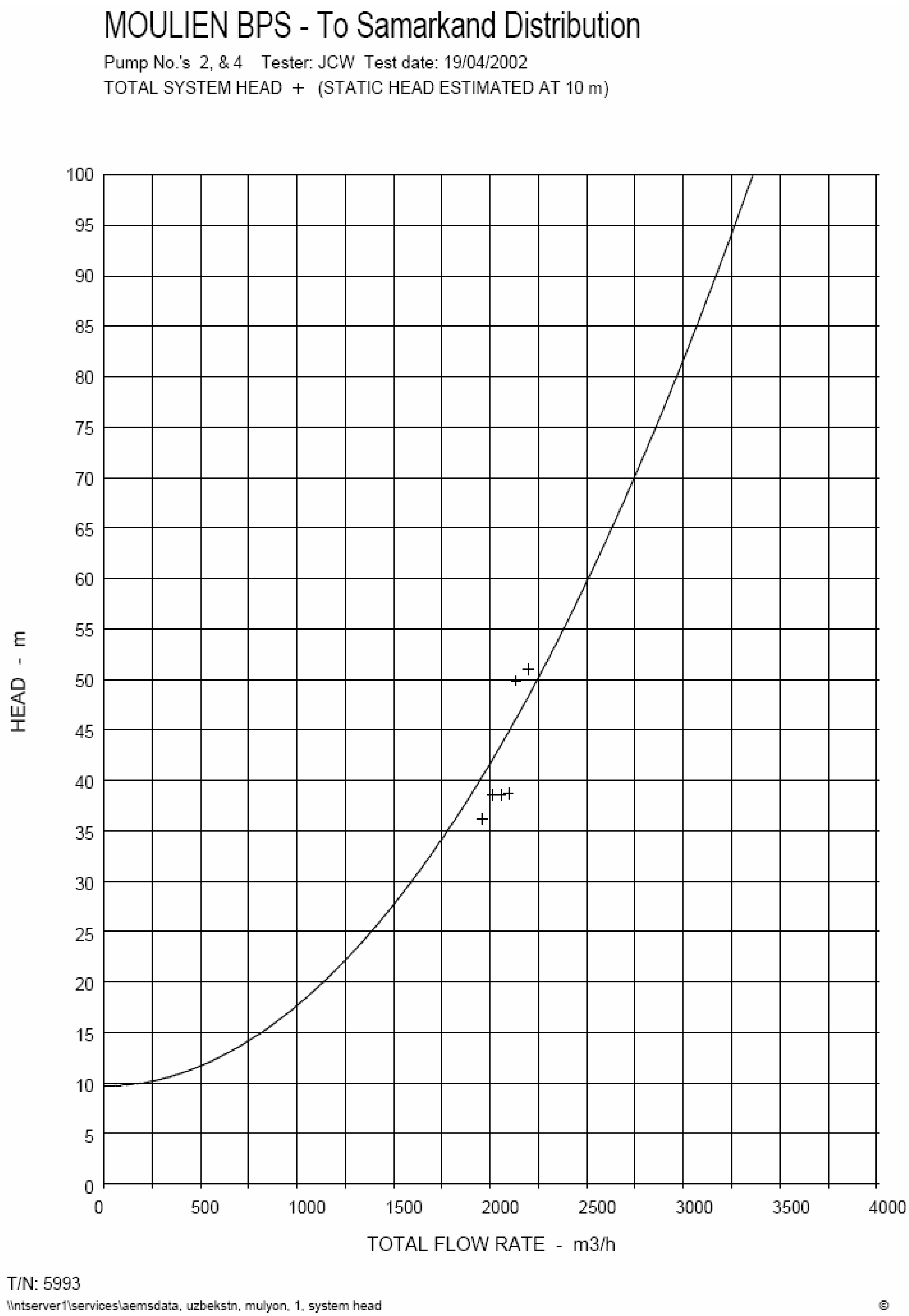
T/N: 5965

\\ntserver1\services\aemsdata, uzbekstn, dahbed, 6, gagarin pump 6 ©

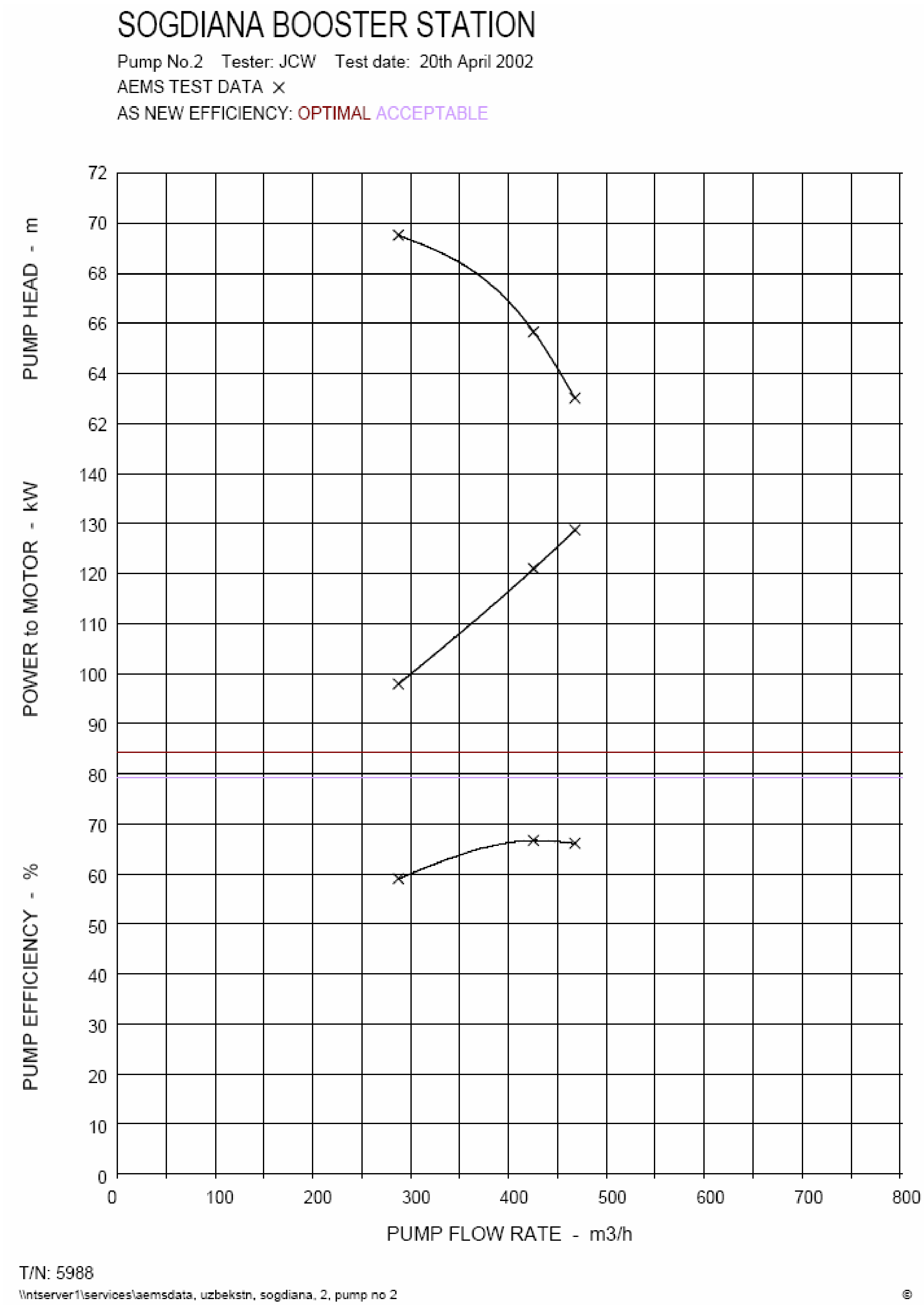
Mouleon Pumping Station Pump-sets: Pump curves 2, 4; & system curve

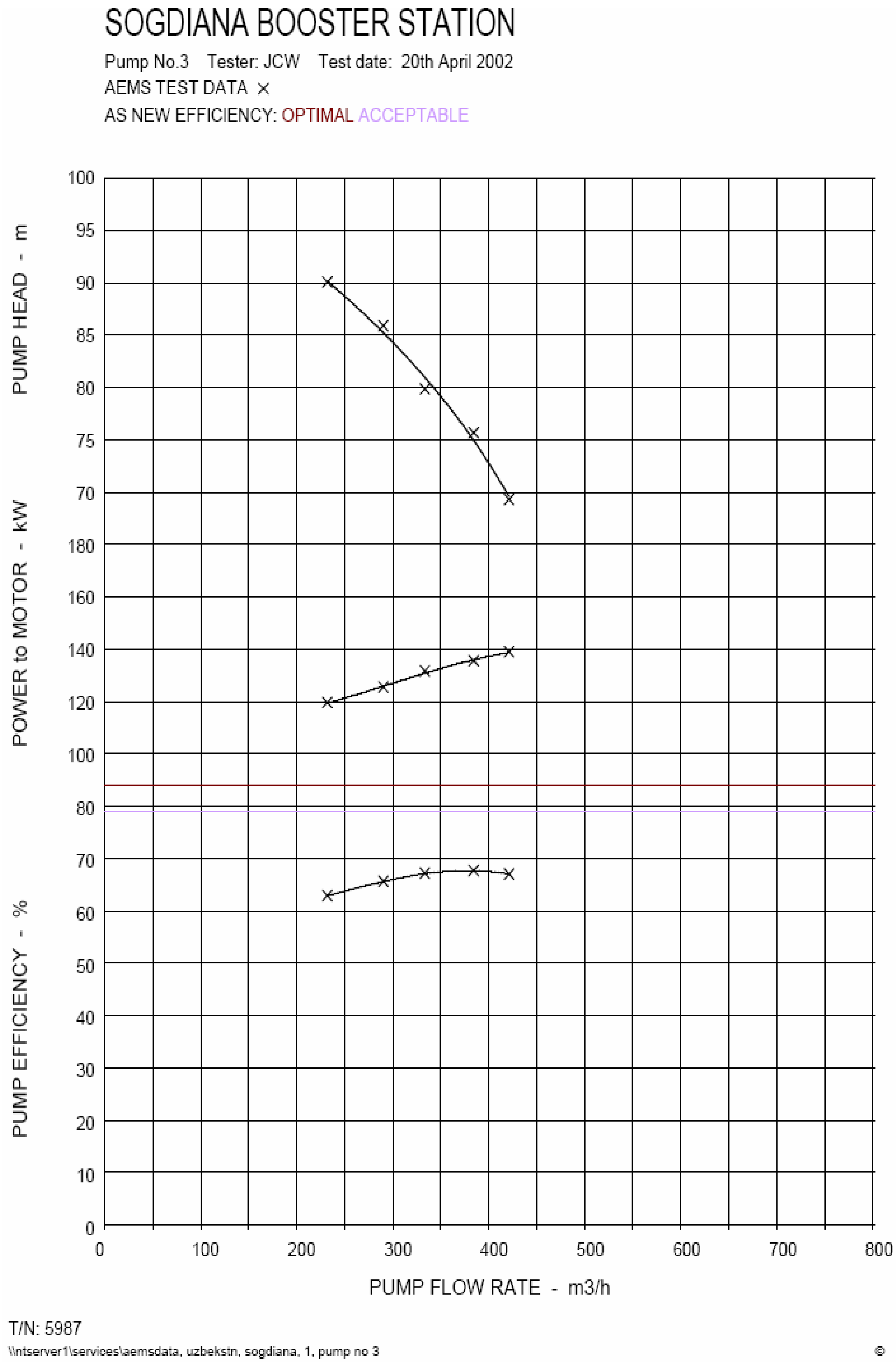


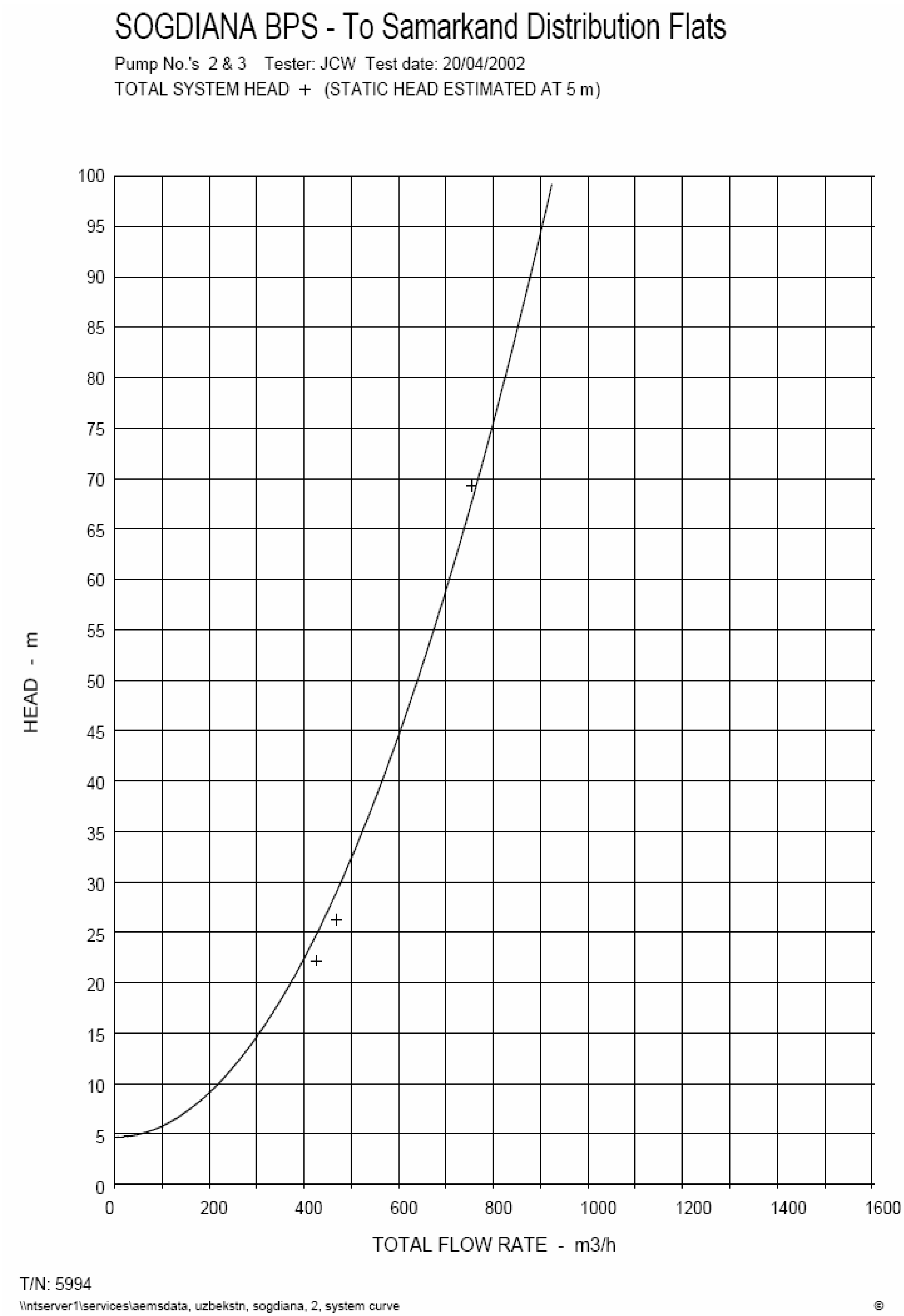

MOULIEN BPS
Pump No: 4 Tester: JCW Test date: 19/04/2002
AEMS TEST DATA ×
AS NEW EFFICIENCY: OPTIMAL ACCEPTABLE
PUMP HEAD - m
POWER to MOTOR - kW
PUMP EFFICIENCY - %
65
60
55
50
45
40
35
800
700
600
500
400
80
70
60
50
40
30
20
10
0
0
800
1600
2400
3200
4000
4800
5600
6400
PUMP FLOW RATE - m3/h
T/N: 5986
\\ntserver1\services\aemsdata, uzbekstn, mulyon, 2, pump 4


MOULIEN BPS - To Samarkand Distribution
Pump No.'s 2, & 4 Tester: JCW Test date: 19/04/2002
TOTAL SYSTEM HEAD + (STATIC HEAD ESTIMATED AT 10 m)
HEAD - m
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0
500
1000
1500
2000
2500
3000
3500
4000
TOTAL FLOW RATE - m3/h
T/N: 5993
\\ntserver1\services\aemsdata, uzbekstn, mulyon, 1, system head
©

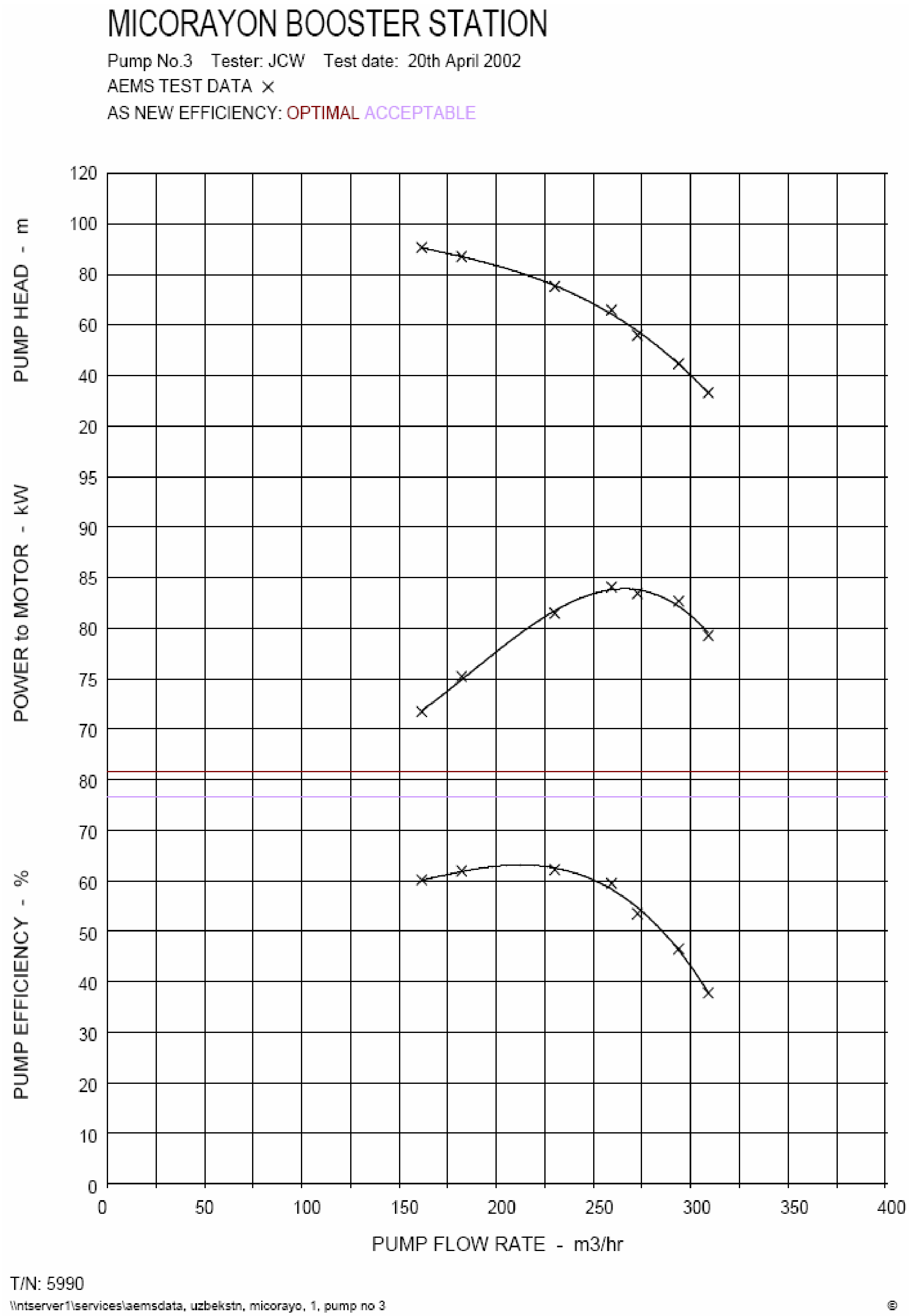
Sogdiana Pumping Station Pump-sets: Pump curves 2, 3; & system curve




SOGDIANA BOOSTER STATION
Pump No.3 Tester: JCW Test date: 20th April 2002
AEMS TEST DATA ×
AS NEW EFFICIENCY: OPTIMAL ACCEPTABLE
PUMP HEAD - m
POWER to MOTOR - kW
PUMP EFFICIENCY - %
100
95
90
85
80
75
70
180
160
140
120
100
80
70
60
50
40
30
20
10
0
0
100
200
300
400
500
600
700
800
PUMP FLOW RATE - m3/h
T/N: 5987
\\ntserver1\services\aemsdata, uzbekstn, sogdiana, 1, pump no 3
©


SOGDIANA BPS - To Samarkand Distribution Flats
Pump No.'s 2 & 3 Tester: JCW Test date: 20/04/2002
TOTAL SYSTEM HEAD + (STATIC HEAD ESTIMATED AT 5 m)
HEAD - m
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
0
200
400
600
800
1000
1200
1400
1600
TOTAL FLOW RATE - m3/h
T/N: 5994
\\ntserver1\services\aemsdata, uzbekstn, sogdiana, 2, system curve
©

Microrayon Pumping Station Pump-sets: Pump curves 3, 5; & system curve

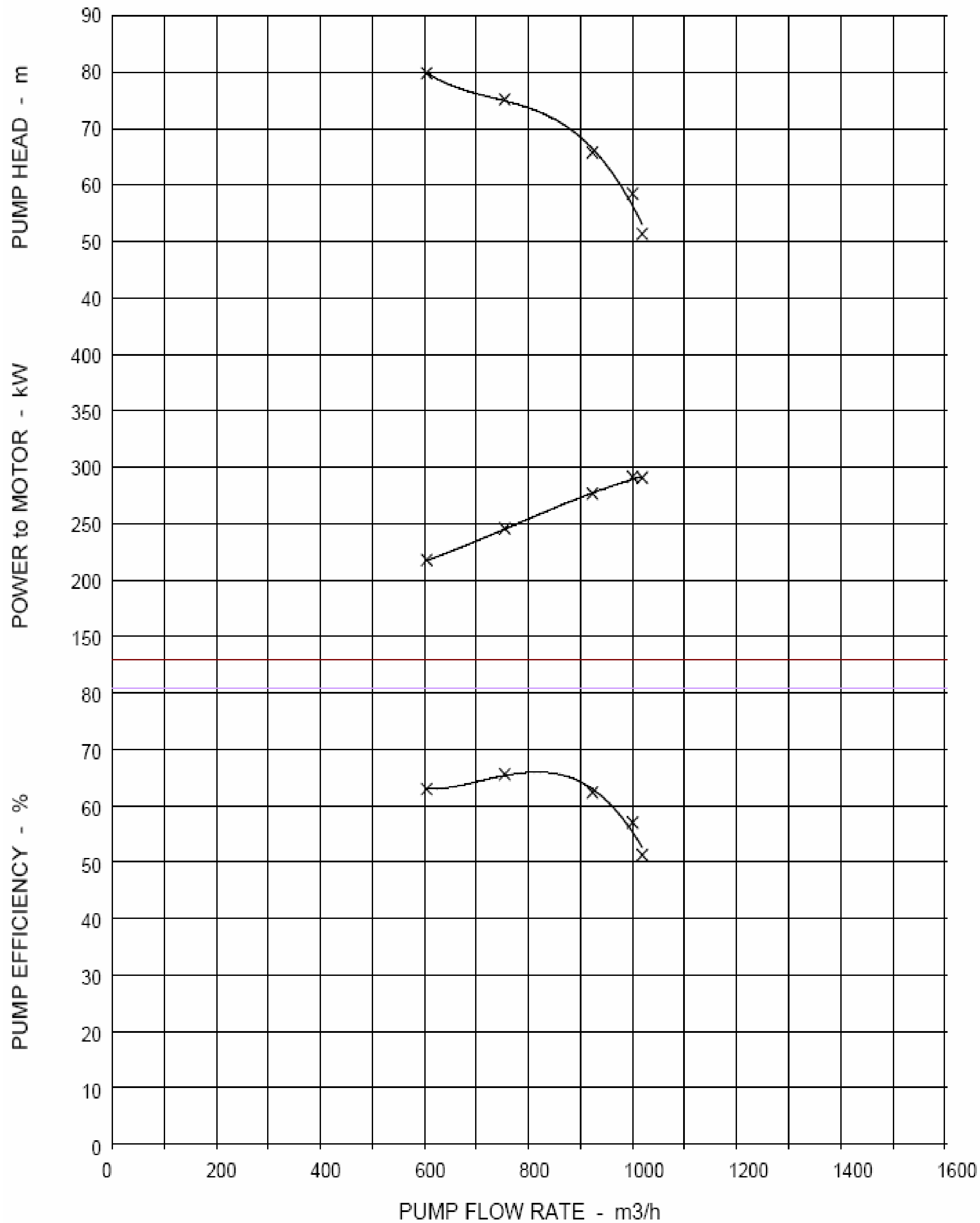


MICORAYON BOOSTER STATION

Pump No.5 Tester: JCW Test date: 20th April 2002

AEMS TEST DATA ×

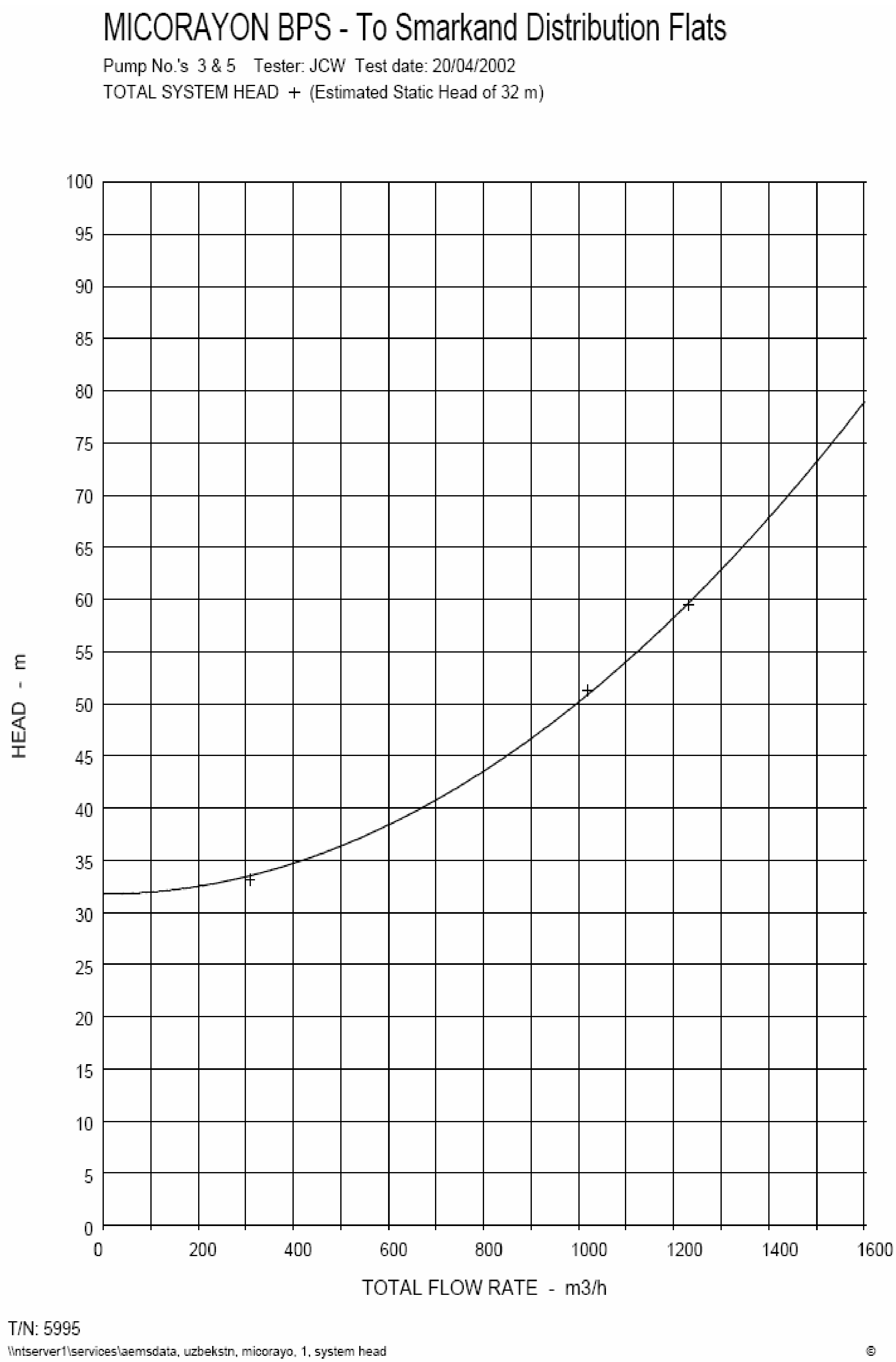
AS NEW EFFICIENCY: OPTIMAL ACCEPTABLE



T/N: 5989

\\ntserver1\services\aemsdata, uzbekstn, micorayo, 2, pump no 5

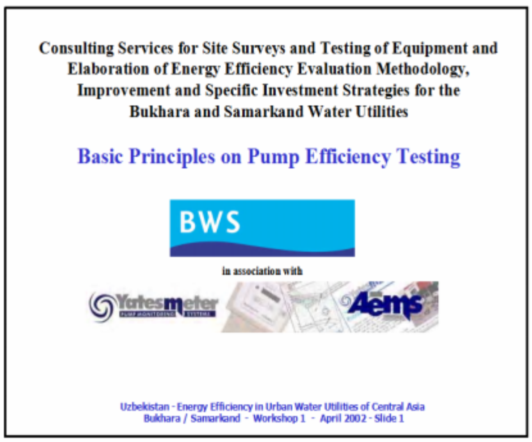
©

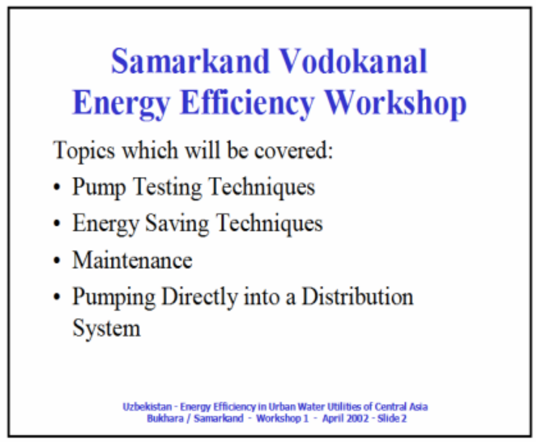

MICORAYON BPS - To Smarkand Distribution Flats
Pump No.'s 3 & 5 Tester: JCW Test date: 20/04/2002
TOTAL SYSTEM HEAD + (Estimated Static Head of 32 m)
HEAD - m
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0
200
400
600
800
1000
1200
1400
1600
TOTAL FLOW RATE - m3/h
T/N: 5995
\\ntserver1\services\aemsdata, uzbekstn, micorayo, 1, system head

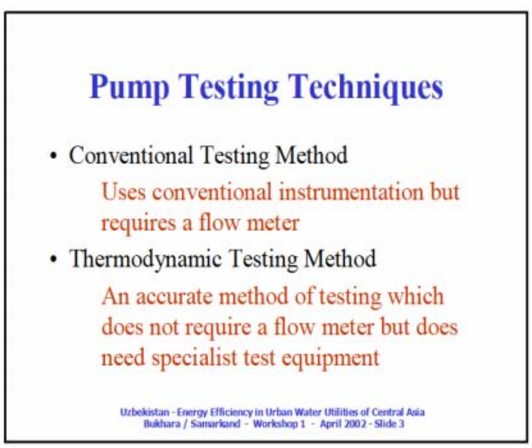
Appendix B

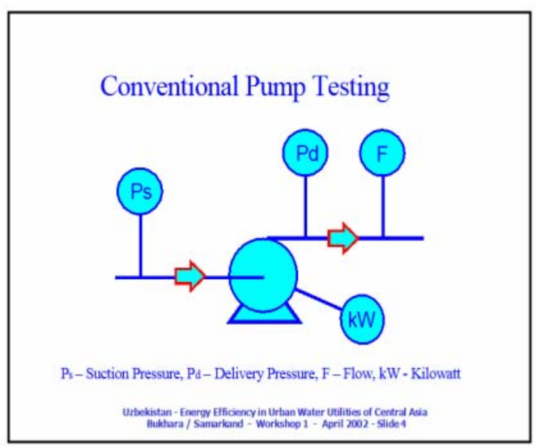
Workshop Hand-outs

Basic Principles on Pump Efficiency Testing Bukhara & Samarkand – Workshop Session 1









Power Consumed

$$P_{gr} = \frac{\rho g Q H}{1000\ \eta_p \eta_m}$$

P_{gr} = electrical power consumed (kW)
ρ = density of fluid (kg/m^3)
g = gravitational constant (9.81 m/s^2)
Q = volumetric flow rate (m^3/s)
H = head developed by the pump (m)
η_p = pump efficiency (decimal)
η_m = motor efficiency (decimal)

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Efficiency from a Conventional Pump Test

$$\eta_p = \frac{\rho Q H}{P_{gr} \eta_m}$$

P_{gr} = electrical power consumed (kW)
ρ = density of fluid (kg/m^3)
g = gravitational constant (9.81 m/s^2)
Q = volumetric flow rate (m^3/s)
H = head developed by the pump (m)
η_p = pump efficiency (decimal)
η_m = motor efficiency (decimal)

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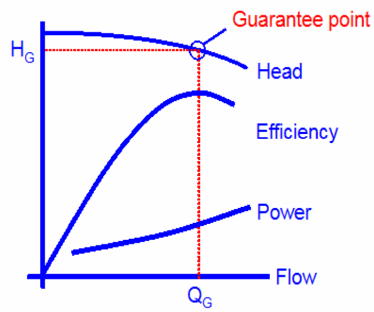
Centrifugal Pump Characteristic



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Thermodynamic Testing Method

- Pump efficiency and performance can be accurately determined on-site
- Accuracy is not sensitive to pipework configuration
- The equipment is easily installed
- Test work can be carried out with the minimum disruption to

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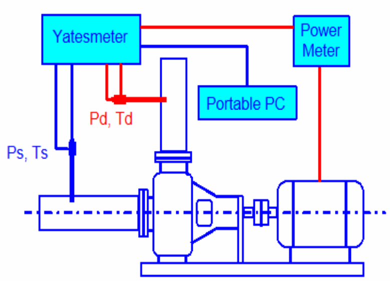
Thermodynamic Pump Testing



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Thermodynamic Pump Testing

$$\text{Efficiency} = \frac{\text{work out}}{\text{work in}}$$

$$\text{work in} = \text{work out} + \text{losses}$$

$$\text{work out} = \rho g Q H$$

$$\text{losses} = \rho Q C_p \Delta T$$

$$\boxed{\text{Efficiency} = \frac{1}{1 + \frac{C_p \Delta T}{gH}}}$$

C_p = specific heat at constant pressure (J/kg.K)

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Energy Cost Saving: Vodokanal's Electricity Cost

- The annual electricity bill for the Vodakanal's potable water pumping stations is in excess of 300 M cyms per annum – even a 10% percentage energy saving would allow 30 M cyms expenditure in other areas

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Energy Cost Saving Techniques

- Regular Pump condition monitoring
- Maintenance of pumps to original specification
- Reduce the number of Throttled Valves
- Scheduling of Pumps in a multiple configuration
- Matching Pumps to system requirements
- Use of Tariffs

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Pump Condition Monitoring

A simple on-site method using basic equipment to measure change in performance rather than absolute performance.

- Pressure gauge on the pump suction and deliveries.
- Determination of flow by accurately measuring the change in level of water in a structure of known dimensions OR magnetic flow meter installed in the delivery main(s) leaving the plant.
- Determination of power used by the pump using incomer kilowatt-hour meter (assuming one pump running) and dividing by time to get kilowatts OR more crudely by use of pump ammeter, multiplying by voltage and assuming the power factor shown on the motor.

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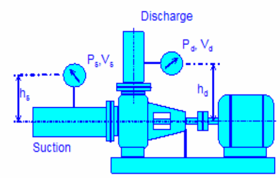
Measuring Total Pump Head Rise



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Equation for Pump Condition Monitoring (Simple Method)

Motor Shaft Power in (kW) = $Pf \times V \times I \times \sqrt{3} \times \eta_m$

Pump Shaft Power (kW) = $\dfrac{G \times Q \times H}{\eta_p}$

Motor Shaft Power = Pump Shaft Power

Total Efficiency $(\eta_p \times \eta_m) = \dfrac{G \times Q \times H}{Pf \times V \times I \times \sqrt{3}}$

Where:
Pf = Power Factor
G = 9.81 Acceleration Due to Gravity
Q = Flow (L/s)
H = Head (metres)
η_p = Pump Efficiency
η_m = Motor Efficiency

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Maintenance of Pumps

- Generally the body of a large pump can give high efficiency for in excess of 30 years. Performance can be increased by the application of a low friction coating.
- A pump impeller may become eroded after time particularly due to the effect of air in the pump (cavitation). The condition of the impellor has a major effect on pump performance and should always be made from the correct materials.
- Pump shaft bearings should last for many years if correctly lubricated and the the pump aligned correctly with the motor. They must be made from the correct materials.
- Pump wearing rings must be to the correct tolerances.
- Pump gaskets must be made from the correct material for the pump to operate without failure over a range of conditions.
- The pump must be assembled using the correct tools and preferably torqued tight.

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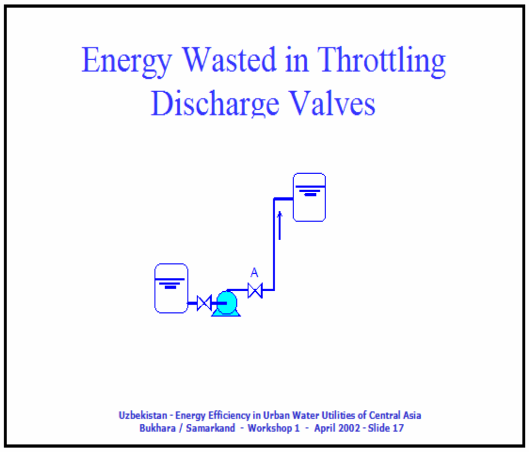
Energy Wasted in Throttling Discharge Valves
A
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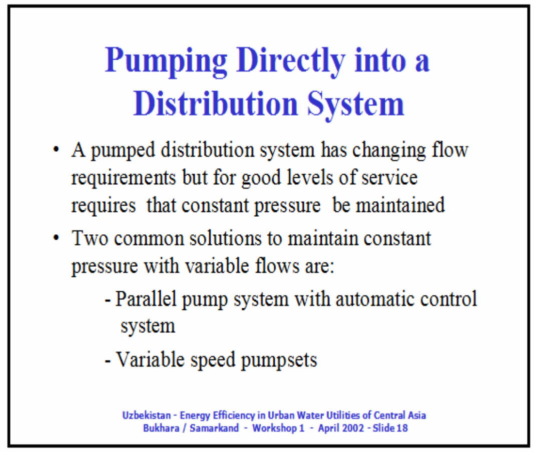
Bukhara / Samarkand - Workshop 1 - April 2002 - Slide 17


Pumping Directly into a Distribution System
• A pumped distribution system has changing flow requirements but for good levels of service requires that constant pressure be maintained
• Two common solutions to maintain constant pressure with variable flows are:
- Parallel pump system with automatic control system
- Variable speed pumpsets
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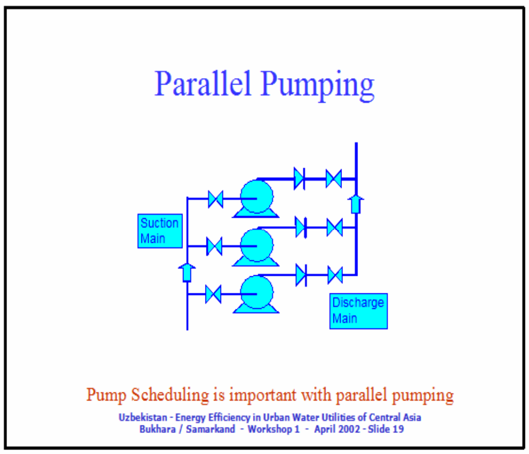
Bukhara / Samarkand - Workshop 1 - April 2002 - Slide 18


Parallel Pumping
Suction Main
Discharge Main
Pump Scheduling is important with parallel pumping
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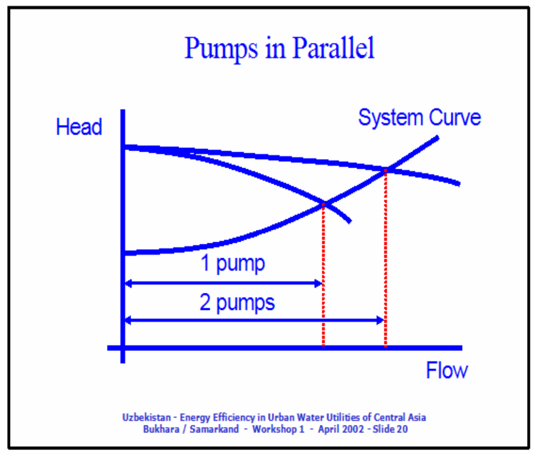
Bukhara / Samarkand - Workshop 1 - April 2002 - Slide 19


Pumps in Parallel
Head
System Curve
1 pump
2 pumps
Flow
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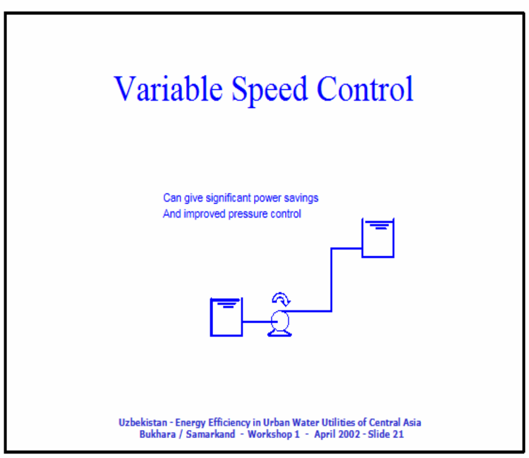
Bukhara / Samarkand - Workshop 1 - April 2002 - Slide 20


Variable Speed Control
Can give significant power savings
And improved pressure control
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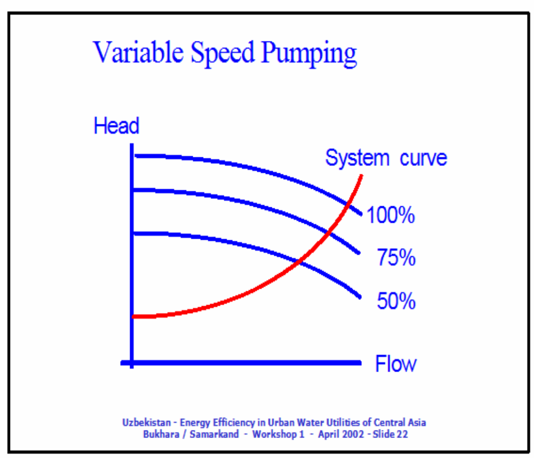
Bukhara / Samarkand - Workshop 1 - April 2002 - Slide 21


Variable Speed Pumping
Head
System curve
100%
75%
50%
Flow
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Variable Speed Pump Equipment

- Electronic equipment which can change the frequency of the electrical supply thus enabling the motor to drive the pump at any chosen speed.
- High voltage variable frequency units are very expensive, less reliable and more difficult to maintain than low voltage (higher current) units.
- Specialist training and spare parts are needed to maintain variable frequency units.

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The Problems of Pumping directly into a large Distribution System with no Distributed Storage

- Negative pressures possible in the distribution system causing probable water contamination
- No balancing storage between production and demand
- No security storage for high demands, fire fighting etc
- Sophisticated equipment necessary to maintain constant system pressure

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Bukhara – Results of Pump Testing - Workshop Session 2

Consulting Services for Site Surveys and Testing of Equipment and Elaboration of Energy Efficiency Evaluation Methodology, Improvement and Specific Investment Strategies for the Bukhara and Samarkand Water Utilities

BWS

in association with

Yatesmeter Aems

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The Purpose of the Mission

- Testing of pumps to determine efficiencies
- Proposal for monitoring indicators and targets for the utility operator
- Preparation of high priority and medium term investment proposals
- Assist the Vodakanal meet the challenges that they face

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Testing of the Pumps

Thermodynamic Method used to determine:

- Flow, Head , Power curves
- Efficiency
- Matching to System

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Sites Visited in Buchara

- Zaravshan Treatment Works
- Shokhrud Treatment Works
- Ku Mazar Pumping Station

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Zaravshan Treatment Works

Pumps tested:

2 Intake Pumpsets, (out of 2)

2 Final Pumpsets (out of 6)

No reserve pumps tested

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Zaravshan Intake Pump 1

Pump No.1	Flow	Head	Power	Efficiency
			11	09-Apr-02
	l/s	m	kW	%
Test Point 1	446.0	11.3	86.2	61.3
Test Point 2	415.8	13.3	87.7	66.0
Test Point 3	336.8	15.3	87.8	61.6
Test Point 4	282.1	16.9	86.2	58.0
Test Point 5	356.1	14.7	88.0	62.4

Advised Pump Duty Point
1000 rpm
1800 m3/hr (500 l/s)
30 m
100 kW

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Zaravshan Intake Pump 2

Normal operation is at test point 1 for all pumpsets (ie delivery valve fully open and lowest head).

Pump No.2	Flow	Head	Power	Efficiency
			10	08-Apr-02
	l/s	m	kW	%
Test Point 1	496.5	13.5	99.7	70.5
Test Point 2	457.1	15.3	100.7	72.5
Test Point 3	408.7	16.9	99.5	72.7
Test Point 4	272.8	20.1	92.5	62.2
Test Point 5	336.3	18.5	95.4	68.4

Advised Pump Duty Point
1000 rpm
1800 m3/hr (500l/s)
30 m
100 kW

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Zaravshan Results - Analysis

Intake Pumpsets

- Intake pump 1 at normal operating point presently gives an efficiency in the order of 61% and could probably be refurbished
- Intake pump 2 at normal operating point presently gives an efficiency in the order of 71% and is likely to be suitable for refurbishment up to 80% or more efficiency.
- The Intake pumps are not sized correctly for duty resulting in a less than optimum efficiency and excessive energy consumption

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Zaravshyan Final Pump 3

Pump No.3	Flow	Head	Power	Efficiency
			9	08-Apr-02
	l/s	m	kW	%
Test Point 1	155.1	46.9	204.1	37.4
Test Point 2	151.1	50.4	201.6	39.7
Test Point 3	143.0	59.7	201.0	44.5
Test Point 4	121.4	73.4	196.4	47.6
Test Point 5	99.0	86.2	187.6	47.7
Test Point 6	66.6	98.7	167.6	41.1

Advised Pump Duty Point
1500 rpm
900 m3/hr (250 l/s)
60 m
200 kW

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Zaravshan Results - Analysis

Final Pumpsets

- Pump No.3 is in very poor condition giving an efficiency of nearly 37% under normal operating conditions – maximum efficiency obtained was 47%.

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Zaravshan Final Pump 6

Pump No.6			8	08-Apr-02
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
Test Point 1	389.4	56.4	331.6	68.6
Test Point 2	365.2	60.0	318.7	71.2
Test Point 3	333.5	63.7	303.2	72.6
Test Point 4	305.9	67.0	291.2	72.9
Test Point 5	263.5	70.7	270.4	71.3
Test Point 6	202.0	75.1	238.6	65.9
Test Point 7	409.3	52.3	335.0	66.2

Advised Pump Duty Point

1500 rpm
1250 m3/hr (347 l/s)
65 m
315 kW

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Bukhara Workshop 2 - April 2002 - Slide 11

Zaravshan Results - Analysis

Final Pumpsets

- Pump No.6 is in relatively good condition giving an efficiency of nearly 69% under normal operating conditions.
- The pump is not correctly matched to duty - as this is approached under test conditions the efficiency rises to 73%.

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Bukhara Workshop 2 - April 2002 - Slide 12

Zaravshan Results - Analysis

- The final pumps delivery directly into the distribution system which has a low static head but a high dynamic head
- The appropriate solution to constantly maintain the desired system pressure with the most efficient use of energy is with variable speed pumpsets

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Bukhara Workshop 2 - April 2002 - Slide 13

Shokhrud Treatment Works

Pumps Tested:

1 Intermediate Pumpset (out of 2)

3 Reserve Final Pumpsets (out of 3)

2 Duty Final Pumpsets (out of 4)

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Bukhara Workshop 2 - April 2002 - Slide 14

Shokhrud Intermediate Pumps

Pump No.2			12	09-Apr-02
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
Test Point 1	1470.5	11.9	286.2	64.0
Test Point 2	1241.1	14.9	291.0	66.4
Test Point 3	1135.8	17.2	295.8	69.2
Test Point 4	955.7	20.0	300.7	66.6
Test Point 5	1325.5	13.6	287.4	65.5
Advised duty point				
5000 m3/hr (1389 l/s)				
30 m Head				
400 kW				

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Bukhara Workshop 2 - April 2002 - Slide 15

Shokhrud Intermediate - Analysis

- The efficiency of Intermediate Pump 2 at Normal Operating Point is in the order of 64%. This pump could probably be refurbished to give an efficiency in the order of 80%.
- The pump duty point has too high head for it to operate at its most efficient – a duty point head in the order of 12 m would be appropriate.
- Fixed speed pumps are most suited to the duty since the process flow through the works is relatively constant and the static head is a large component of the total head.

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Bukhara Workshop 2 - April 2002 - Slide 16

Shokhrud – Reserve Final No1

Reserve Final Pump No.1				
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
Test Point 1	750.4	71.53	813.4	66.6
Test Point 2	1131	44.34	896.9	56.5
Test Point 3	983.1	59.77	877.9	67.6
Test Point 4	355.8	80.09	639.8	45
Test Point 5	639.6	75.33	778	62.5
1000 rpm				
3200 m3/hr				
75m				
800kW				

Shohkrud Reserve Final No 2

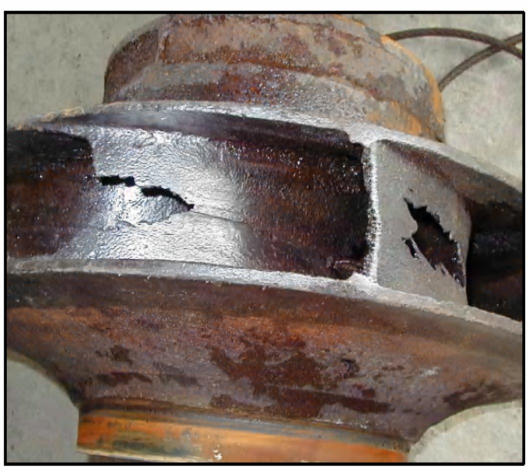
Pump No.2			14	10-Apr-02
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
Test Point 1	550.5	20.34	322.4	35.7
Test Point 2	516.2	32.66	345.7	50.2
Test Point 3	480.2	47.78	352.4	67
Test Point 4	372.9	62.35	316.7	75.6
Test Point 5	158.9	74.96	211.1	58.2
Advised duty point				
1000 rpm				
1500 m3/hr (416 l/s)				
40 m	(Suspect actual is 60 m)			
315 kW				

Shohkrud Reserve Final No 3

Pump No.3			13	10-Apr-02
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
Test Point 1	444.3	28.23	306.7	42.1
Test Point 2	426.7	35.65	307	51
Test Point 3	375.8	42.65	294.7	56
Test Point 4	352.8	49.51	301.9	59.6
Test Point 5	322.3	57.69	301.3	63.5
Test Point 6	262.7	65.11	281.3	62.6
Test Point 7	115.5	73.46	223.7	39.1
Advised duty point				
1000 rpm				
1500 m3/hr (416 l/s)				
40m	(Suspect actual is 60 m)			
315 kW				

Shokrud Duty Final No 5

Pump No.5				
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
	0			
Test Point 1	1003	48.08	843.2	57.4
Test Point 2	1126	24.2	764.6	35.8
Test Point 3	1104	30.01	795.1	41.8
Test Point 4	633.6	50.9	700.2	46.3
Advised duty point				
1000 rpm				
3200 m3/hr				
75 m				
800 kW				



Shohkrud Duty Final No 7

Pump No.7				
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
Test Point 1	1143	39.84	703.9	65.3
Test Point 2	1258	33.25	715.4	59
Test Point 3	985.8	49.29	667.2	73.5
Test Point 4	777.2	57.78	600.9	75.5
Test Point 5	424.3	67.07	469.4	61.4
Test Point 6	582.6	63.83	529.7	71
Advised duty point				
1000 rpm				
3200 m3/hr				
75 m				
800 kW				

Shohkrud Final Pumps Analysis

- The efficiency of Duty and Reserve Final Pumps at Normal Operating Point is generally poor although Reserve Final 1 and Duty Final 7 would be suitable for refurbishment if the duties were appropriate.
- The pumps are operating beyond their stable operating range with erratic results and overload of the motor in excess of 10% under certain conditions
- The appropriate solution to constantly maintain the desired system pressure with the most efficient use of energy is with variable speed pumpsets.
- It would be most appropriate to replace all these pumpsets with variable speed units more correctly sized to the duty. The exact configuration and duties requires further consideration.

Ku Mazar Pumping Station

Pumps Tested:

- 4 Pumpsets (out of 6)

Ku Mazar Pump 2

Pump No.2			20	13-Apr-02
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
Test Point 1	786.8	33.0	466.8	56.4
Test Point 2	744.3	40.2	471.9	64.3
Test Point 3	630.9	52.8	465.7	72.4
Test Point 4	499.1	61.6	442.4	70.4
Test Point 5	310.0	70.1	385.0	57.3
Duty Advised				
1000 rpm				
2500 m3/hr	(694 l/s)			
62m				
630 kW	Synch			

Ku Mazar Pump 3

Pump No.3			21	13-Apr-02
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
Test Point 1	786.9	34.4	518.8	52.9
Test Point 2	731.1	45.0	533.5	62.5
Test Point 3	708.4	53.3	548.4	69.7
Test Point 4	642.7	62.5	529.4	76.8
Test Point 5	491.5	71.4	479.7	74.2

Duty Advised
1000 rpm
2500 m3/hr (694 l/s)
62m
630 kW Sych

Ku Mazar Pump 5

Pump No.5			19	12-Apr-02
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
Test Point 1	797.4	60.4	742.0	65.5
Test Point 2	727.2	68.5	717.0	70.1
Test Point 3	633.9	74.9	678.1	70.7
Test Point 4	338.7	81.6	541.2	51.6
Test Point 5	461.1	79.7	598.5	62.0

Duty Advised
1000
3200 m3/hr (889 l/s)
75m
800 kW Synch

Ku Mazar Pump 6

Pump No.6			18	12-Apr-02
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
Test Point 1	702.5	82.2	960.1	60.3
Test Point 2	516.7	100.9	868.7	60.2
Test Point 3	652.5	92.5	949.5	63.8
Test Point 4	585.4	96.8	915.5	62.2
Test Point 5	426.7	104.8	817.9	54.9

Duty Advised
1000 rpm
2000 m3/hr (565 l/s)
100m
800kW

Ku Mazar Pump Analysis

- All of the four pumps tested at Ku Mazar have a reasonable efficiency and could be refurbished.
- Pumps 1 and 2 have duty points (62 m) meeting the system requirements. Pumps 5 & 6 have too high duty point head resulting in low efficiencies

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Bukhara Workshop 2 - April 2002 - Slide 29

Bukhara – Plants & Buildings - Workshop Session 3

Consulting Services for Site Surveys and Testing of Equipment and Elaboration of Energy Efficiency Evaluation Methodology, Improvement and Specific Investment Strategies for the Bukhara and Samarkand Water Utilities

BWS

in association with

Yatesmeter Aems

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Bukhara
Other Plant and Buildings

- Electric Motors
- HV Switchgear
- LV Switchgear
- Cables
- Instrumentation
- Buildings

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Electric Motors

- Some of the pump motors are about 30 years old
- All motors have been rewound many times
- The failure rate of motors is very high- some lasting less than one year after a rewind.
- Recommendation: Scrap them all and when the duties of the final pumpsets are determined – purchase as a matched pair.

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HV Switchgear

- The HV Switchgear is about 30 years old – this is not normally considered beyond useful life by Western standards.
- The HV switchgear is in poor condition and certainly does not meet high safety standards
- Whilst the switchgear seems to be fairly reliable – the condition requires that it be replaced in the medium term or as necessary for the new arrangement of pumpsets
- Electrical System Protection equipment is suspect

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LV Switchgear

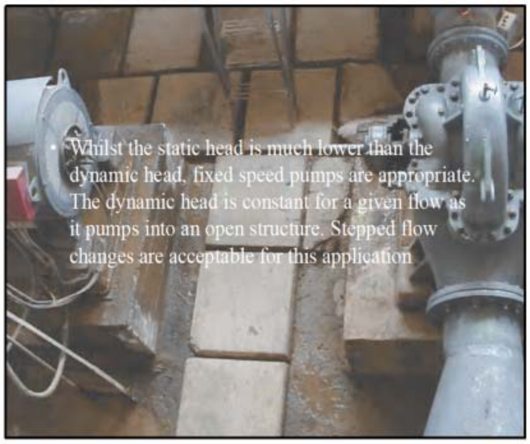
- Generally in very poor condition but maintainable.
- All should be replaced – including electrical building services
- Poor protection against electric shock
- Suspect electrical system protection

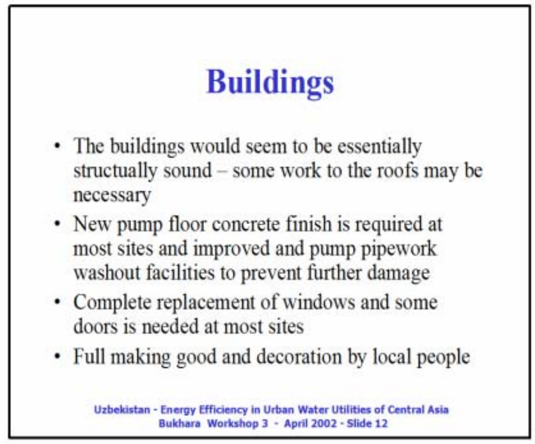
Cables

- Cables faults are rare
- The majority of the HV cables are pvc/paper/resin insulated – some with armouring.
- Non of the insulation resistance on the cables was tested and no data was available
- The quality of installation of the cables was poor – often not correctly supported.
- Terminations into motors was poor - often secondary terminations after terminal box, no terminal box cover etc
- Cabling should be replaced at the same time as HV and LV switchgear as a medium term investment or otherwise to meet requirements of new pumpsets

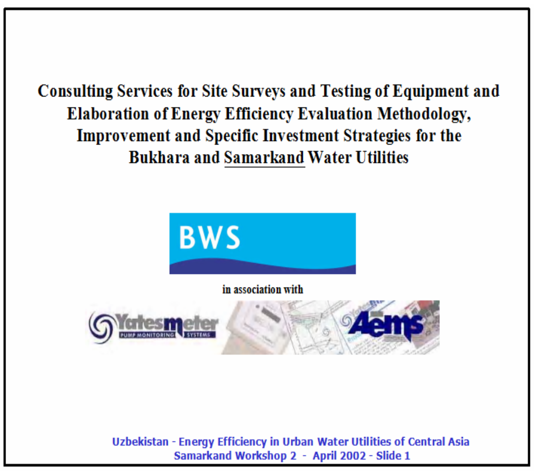
Instrumentation

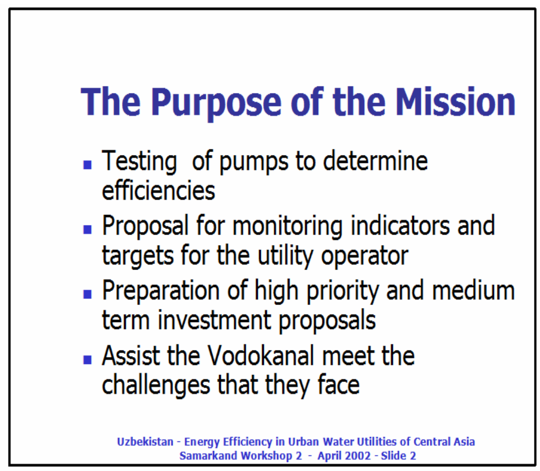
- The is very little instrumentation at the Treatment Works and Pumping Stations either electrical, hydraulic or water quality
- A high priority should be to install relatively low cost hydraulic pressure, flow and level instrumentation. Kilowatt Hour meters at all plants should operate
- This will assist greatly in operating plant efficiently, improving levels of service and understanding how the system is performing
- A full computer system may not be appropriate or necessary for several years

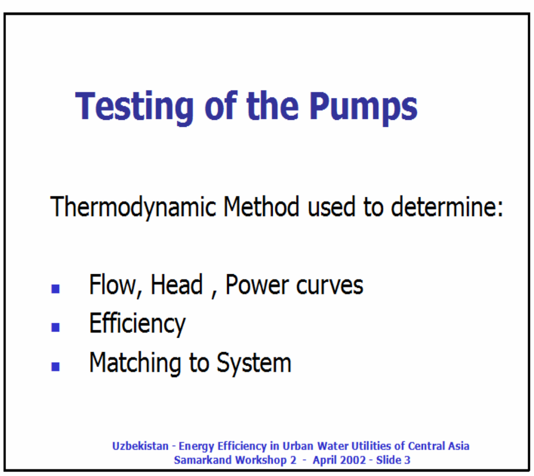


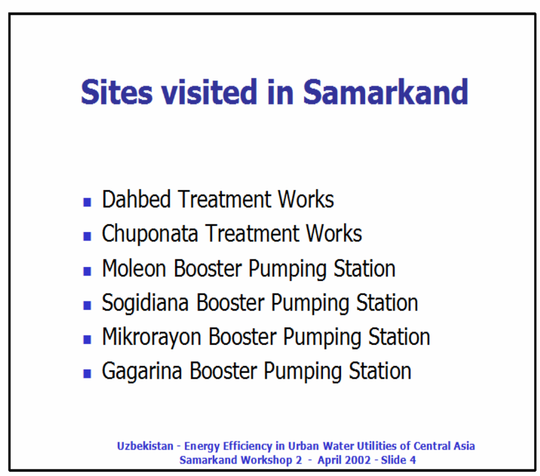


Samarkand – Results of Pump Testing - Workshop Session 2









Dahbed Treatment Works

Pumps tested:

3 Well Pumpsets,
4 Final Pumpsets

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Dahbed Well Pump 1

Pump No. CBKN1	1		04-Apr-02	
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
Test Point 1	54.0	25.2	29.8	44.8
Test Point 2	50.7	26.0	29.2	44.2
Test Point 3	45.6	27.5	29.3	42.0
Test Point 4	39.9	29.1	29.1	39.1
Test Point 5	34.6	30.3	28.4	36.1

Advised Pump Duty
Flow 255m3/hr (70.8 l/s)
Head 40 m
Power 32 kW

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Samarkand Workshop 2 - April 2002 - Slide 6

Dahbed Well Pump 2

Pump No. CBKN2	2		05-Apr-02	
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
Test Point 1	74.4	25.3	37.8	48.8
Test Point 2	65.0	28.7	36.3	50.3
Test Point 3	55.3	29.8	34.7	46.6
Test Point 4	41.4	32.8	31.6	42.2
Test Point 5	69.8	27.2	37.2	50.0

Advised Pump Duty
Flow 255m3/hr (70.8 l/s)
Head 40 m
Power 32 kW

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Samarkand Workshop 2 - April 2002 - Slide 7

Dahbed Well Pump 4

Pump No. CBKN4	3		05-Apr-02	
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
Test Point 1	41.3	23.9	31.3	30.9
Test Point 2	37.6	24.3	31.1	28.8
Test Point 3	33.3	25.4	31.1	26.7
Test Point 4	28.0	26.3	30.7	23.5
Test Point 5	21.0	27.7	29.3	19.4

Advised Pump Duty
Flow 255m3/hr (70.8 l/s)
Head 40 m
Power 32 kW

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Dahbed Well Pumps - Analysis

- Two of the pumpsets tested had efficiencies substantially less than 50%.
- If the sample of pumpsets tested can be taken to be representative then replacement of them all will give substantially improved yield and reduced energy costs.
- The well pumpset switchgear is in poor condition and requires replacement.
- It is suspected that sand is increasing wear on the well pumpsets.

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Samarkand Workshop 2 - April 2002 - Slide 9

Dahbed Final Pump 2

Pump No.2	5		06-Apr-02	
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
Test Point 1	426.6	106.4	649.2	71.5
Test Point 2	399.6	112.3	633.9	72.4
Test Point 3	350.4	120.8	595.6	72.6
Test Point 4	269.8	128.1	528.2	66.9
Test Point 5	150.7	132.9	428.7	47.9

Advised Pump Duty
Flow 1250 m3/hr (347 l/s)
Head 125 m
Power 630 kW

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Dahbed Final Pump 3

Pump No.3			4	06-Apr-02
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
Test Point 1	330.4	116.1	613.2	64.0
Test Point 2	309.7	121.1	590.9	64.9
Test Point 3	371.5	100.8	667.4	57.4
Test Point 4	261.9	128.4	542.3	63.4
Test Point 5	173.6	135.8	475.0	50.8

Advised Pump Duty
Flow 1250 m3/hr (347 l/s)
Head 125m
Power 630 kW

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Dahbed Final Pump 5

Pump No.5			7	06-Apr-02
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
Test Point 1	306.1	134.2	604.8	69.5
Test Point 2	367.4	128.3	663.6	72.7
Test Point 3	160.2	135.3	453.6	48.9
Test Point 4	315.2	133.2	612.2	70.1
Test Point 5	241.9	136.1	533.3	63.1

Advised Pump Duty
Flow 1250 m3/hr (347 l/s)
Head 125m
Power 630 kW

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Dahbed Final Pump 6

Pump No.6			6	06-Apr-02
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
Test Point 1	452.9	104.7	714.7	67.9
Test Point 2	391.7	116.8	658.6	71.1
Test Point 3	350.2	122.3	623.0	70.3
Test Point 4	293.7	128.5	576.0	67.0
Test Point 5	426.8	110.5	691.1	69.8

Advised Pump Duty
Flow 1250 m3/hr (347 l/s)
Head 125m
Power 630 kW

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Dahbed Final Pumps - Analysis

- Dahbed Final Pumps have efficiencies in the order of 70% and could probably be refurbished to a good standard.
- Variable speed pumpsets are normally appropriate for pumping into a closed distribution system but are impractical in larger sizes – a multiple pump arrangement is probably the most suitable.
- The general condition of the treatment works is extremely poor and remedial work is urgently required

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Chuponata Treatment Works

Pumps Tested:

3 Well Pumpsets

1 Final Water Pumpset

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Chuponata Well Pumpset 14

Pump No.14			24	17-Apr-02
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
Test Point 1	87.0	15.7	35.7	37.4
Test Point 2	77.0	19.1	35.4	40.7
Test Point 3	68.0	21.7	34.8	41.5
Test Point 4	59.0	23.4	34.2	39.7
Test Point 5	49.0	25.9	32.9	37.8

Advised Pump Duties
Flow 255m3/hr (70.8 l/s)
Head 40 m
Power 32 kW

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Chuponata Well Pumpset 15

Pump No.15			23	17-Apr-02
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
Test Point 1	67.2	14.3	36.7	25.7
Test Point 2	60.6	17.5	36.4	28.6
Test Point 3	53.7	20.1	35.8	29.6
Test Point 4	45.7	23.1	35.0	29.6
Test Point 5	37.5	25.5	33.8	27.7
Test Point 6	32.5	26.5	35.3	23.9

Advised Pump Duties
Flow 255m3/hr (70.8 l/s)
Head 40 m
Power 32 kW

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Samarkand Workshop 2 - April 2002 - Slide 17

Chuponata Well Pumpset 17

Pump No.17			22	17-Apr-02
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
Test Point 1	74.7	10.7	26.9	29.1
Test Point 2	69.1	13.7	27.1	34.4
Test Point 3	64.9	16.4	26.9	38.9
Test Point 4	59.3	19.0	26.8	41.3
Test Point 5	53.9	20.7	26.8	40.9
Test Point 6	48.4	22.6	26.6	40.4
Test Point 7	43.2	24.5	26.7	38.9

Advised Pump Duties
Flow 255m3/hr (70.8 l/s)
Head 40 m
Power 32 kW

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Samarkand Workshop 2 - April 2002 - Slide 18

Chuponata Well Pumpsets - Analysis

- The efficiency of the sample of well pumps tested is extremely poor – less than 40%.
- Taking the sample to be representative of all the well pumpsets – urgent replacement of all well pumpsets is required to both increase yield and reduce energy cost.
- It is suspected that sand is increasing wear on the well pumpsets.
- The new motor starter equipment supplied by the French is of a good standard but might pose future maintenance problems.

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Samarkand Workshop 2 - April 2002 - Slide 19

Chuponata Final Pumpset 1

Pump No.1			25	18-Apr-02
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
Test Point 1	1359.6	85.2	1365.7	85.3
Test Point 2	1414.8	82.5	1392.4	84.3
Test Point 3	1165.7	92.3	1282.6	84.4
Test Point 4	1080.2	95.3	1242.3	83.3
Test Point 5	958.1	100.2	1191.8	81.0
Test Point 6	1286.3	88.7	1342.6	85.4

Advised Pump Duties
Flow 4000 m3/hr (1111 l/s)
Head 95 m
Power1335 kW

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Samarkand Workshop 2 - April 2002 - Slide 20

Chuponata Final Pumpsets - Analysis

- Final Pumpset 6 is in excellent condition and extremely closely matches the manufactures test curves. The efficiency is excellent at 83%.
- The motor and switchgear are undersized for the pump operating at higher flows (lower pressure) than design duty point. The system characteristic is such that motor overload will occur unless the pump is throttled.
- It may be appropriate to consider slight re-engineering of the impeller to more closely match the system.

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Samarkand Workshop 2 - April 2002 - Slide 21

Mouleon Pumping Station

Pump 2 tested
Pump 3 tested

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Moulien Pump No. 2

Pump No.2			26	19-Apr-02
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
Test Point 1	989.6	49.1	635.8	77.5
Test Point 2	1008.6	48.6	640.7	77.6
Test Point 3	875.5	53.9	612.5	78.0

Advised Duties
Flow 3600 m3/hr (1000 l/s)
Head 52 m
Power 630 kW

Moulien Pump 3

Pump No.4			27	19-Apr-02	
	Flow	Head	Power	Efficiency	
	l/s	m	kW	%	
Test Point 1	890.0	36.9	584.5	57.0	
Test Point 2	865.5	40.5	590.5	60.2	Cavitation
Test Point 3	877.3	46.4	608.3	67.8	
Test Point 4	551.2	61.7	522.7	65.9	
Test Point 5	394.9	63.4	473.0	53.7	
Test Point 6	582.7	61.0	531.1	67.8	
Test Point 7	676.5	59.0	563.3	71.7	

Advised Duties
Flow 3600 m3/hr (1000 l/s)
Head 52 m
Power 630 kW

Analysis of Moulien Pumpsets

- The pumpsets are in very good condition – Pump 2 had an eficiency in the order of 78%
- Pump 3 is not operating correctly due to an obstruction in the suction pipework – this is causing cavitation and severely compromising efficiency.
- The station and switchgear are all in good order and not additional works can recommended to the pumpsets at this stage.
- In the future variable speed pumpsets could improve matching of pumpsets to system

Sogdiana Pumping station

Pumpset 3 tested

Pumpset 5 tested

Sogdiana - Pump 2

Pump No.2			29	20-Apr-02
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
Test Point 1	79.6	69.5	98.3	59.5
Test Point 2	129.6	63.0	128.9	66.5
Test Point 3	117.9	65.7	121.2	67.1
Test Point 4				
Test Point 5				

Advised Pump Duties
Flow 500 m3/hr (139 l/s)
Head 63 m
Power 160 kW

Sogdiana - Pump 3

Pump No.3			28	20-Apr-02
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
Test Point 1	129.3	69.4	139.5	67.4
Test Point 2	116.7	75.8	136.1	68.1
Test Point 3	106.5	79.9	132.2	67.6
Test Point 4	92.4	85.9	126.2	66.1
Test Point 5	80.5	90.1	120.2	63.4
Test Point 6	64.2	94.9	110.9	57.8
Test Point 7				

Advised Pump Duties
Flow 500 m3/hr (139 l/s)
Head 70 m
Power 160 kW

Sogdiana - Analysis

- Both pumpsets tested have a fair efficiency – commensurate with age, duty and maintenance.
- The operation of pumpsets 2 and 3 together is not efficient due to the lower duty head of pump 2.
- The condition of the station is poor and the design of the pipework arrangement particularly bad.
- The pumps should be replaced with a new duty/standby pair of variable speed units able to work efficiently to a changing distribution system characteristic

Microrayon Pumping Station

Pumpset 3 tested

Pumpset 5 tested

Microrayon Pumpset 3

Pump No.3			31	20-Apr-02
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
Test Point 1	75.6	56.1	83.5	54.0
Test Point 2	85.6	33.4	79.4	38.3
Test Point 3	81.4	45.0	82.8	47.0
Test Point 4	71.9	66.1	84.2	59.9
Test Point 5	63.7	75.4	81.6	62.6
Test Point 6	50.5	87.1	75.4	62.4
Test Point 7	44.8	90.7	71.9	60.6

Advised Pumpset Duties
Flow 400 m3/hr (111l/s)
Head 105 m
Power 160 kW

Microrayon Pumpset 5

Pump No.5			30	20-Apr-02
	Flow	Head	Power	Efficiency
	l/s	m	kW	%
Test Point 1	282.3	51.4	291.7	51.7
Test Point 2	277.1	58.5	292.8	57.5
Test Point 3	255.5	65.8	277.9	62.8
Test Point 4	209.0	75.2	247.0	66.0
Test Point 5	167.5	79.9	219.1	63.4

Advised Pump Duties
Flow 540 m3/hr (150l/s)
Head 90 m
Power 250kW

Microrayon Pumping Station – Analysis

- Both pumpsets are normally operating at low efficiencies – slightly above 50%
- The pumps are not operating at the designed duty points – the flow is higher and the head lower. This results in an efficiency below the pumps capability.
- The pumps should be replaced with a new duty/standby pair of variable speed units able to work efficiently to a changing distribution system characteristic

Samarkand – Plants & Buildings - Workshop Session 3

Consulting Services for Site Surveys and Testing of Equipment and Elaboration of Energy Efficiency Evaluation Methodology, Improvement and Specific Investment Strategies for the Bukhara and Samarkand Water Utilities

BWS

in association with

Uzbekistan - Energy Efficiency in Urban Water Utilities of Central Asia
Samarkand Workshop 3 - April 2002 - Slide 1

Samarkand Other Plant and Buildings

- Electric Motors
- HV Switchgear
- LV Switchgear
- Pumping Station Pipework
- Instrumentation
- Buildings
- House Keeping

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Samarkand Workshop 3 - April 2002 - Slide 2

Electric Motors

- Many of the pump motors are about 30 years old
- All motors have been rewound many times
- The failure rate of motors is very high- some lasting less than one year after a rewind.
- Recommendation: Scrap them all and when the duties of the pumpsets are determined – purchase as a matched pair.

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HV Switchgear

- Much of the HV Switchgear is about 30 years old – this is not normally considered beyond useful life by Western standards.
- The HV switchgear is in poor condition and certainly does not meet high safety standards
- Whilst the switchgear seems to be fairly reliable – the condition requires that it be replaced in the medium term or as necessary for the new arrangement of pumpsets
- Electrical System Protection equipment is suspect

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Samarkand Workshop 3 - April 2002 - Slide 5

LV Switchgear

- Generally in poor condition but maintainable.
- All should be replaced – including electrical building services
- Poor protection against electric shock
- Suspect electrical system protection

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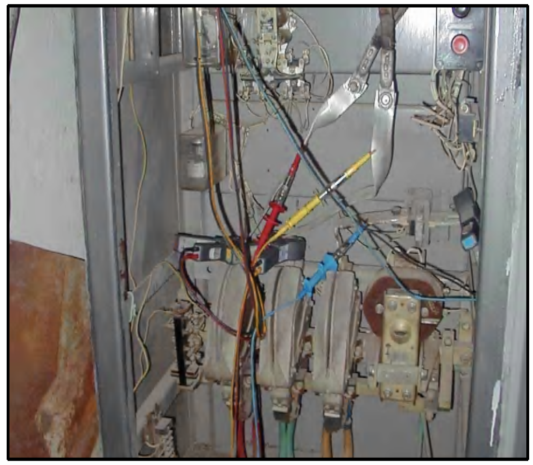
Samarkand Workshop 3 - April 2002 - Slide 7



Pumping Station Pipework

- The design of the pipework at some sites was very imaginative but not good hydraulically.
- Every change of direction of the pipework adds additional hydraulically losses.
- Some pipework configurations if incorrectly sized and installed will affect pump performance

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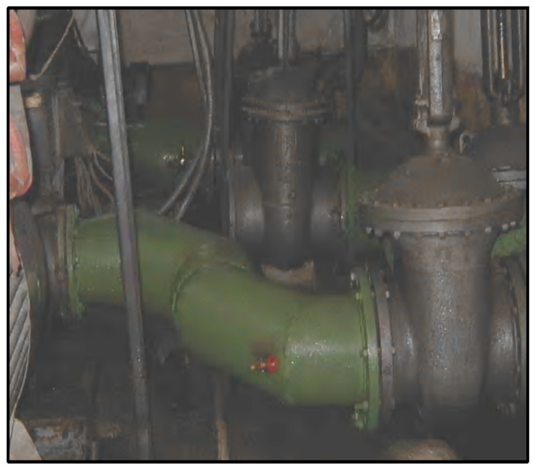
Samarkand Workshop 3 - April 2002 - Slide 9



Instrumentation

- Some hydraulic instrumentation has been installed at the Treatment Works and Pumping Stations and this is good.
- A priority should be to install more relatively low cost hydraulic pressure, flow and level instrumentationThis will assist greatly in operating plant efficiently, improving levels of service and understanding how the system is performing
- A full computer system may not be appropriate or necessary for several years

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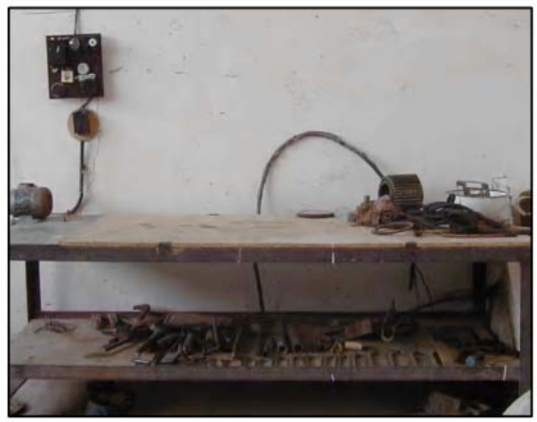
Buildings

- The buildings would seem to be essentially structually sound – some work to the roofs may be necessary – especially Dahbed
- New pump floor concrete finish is required at most sites and improved and pump pipework washout facilities to prevent further damage
- Replacement of windows and some doors is needed at some sites
- Full making good and decoration by local people

Housekeeping

- The local management of sites in has a profound effect on the condition of the buildings and plant
- A well managed site is reflected in the cleanness, safety, adherence to procedures and facilities for maintenance.
- Samarkand has examples of the best and worst.



Joint UNDP/World Bank

ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAMME (ESMAP)

LIST OF TECHNICAL PAPER SERIES

Region/Country	*Activity/Report Title*	*Date*	*Number*
	SUB-SAHARAN AFRICA (AFR)		
Africa	Power Trade in Nile Basin Initiative Phase II (CD Only): *Part I: Minutes of the High-level Power Experts Meeting; and Part II: Minutes of the First Meeting of the Nile Basin Ministers Responsible for Electricity*	04/05	067/05
Chad	Revenue Management Seminar. Oslo, June 25-26, 2003. (CD Only)	06/05	075/05
Côte d'Ivoire	Workshop on Rural Energy and Sustainable Development, January 30-31, 2002. (French Only)	04/05	068/05
Ethiopia	Phase-Out of Leaded Gasoline in Oil Importing Countries of Sub-Saharan Africa: The Case of Ethiopia - Action Plan.	12/03	038/03
	Sub-Saharan Petroleum Products Transportation Corridor: Analysis And Case Studies	03/03	033/03
	Phase-Out of Leaded Gasoline in Sub-Saharan Africa	04/02	028/02
	Energy and Poverty: How can Modern Energy Services Contribute to Poverty Reduction	03/03	032/03
East Africa	Sub-Regional Conference on the Phase-out Leaded Gasoline in East Africa. June 5-7, 2002.	11/03	044/03
Kenya	Field Performance Evaluation of Amorphous Silicon (a-Si) Photovoltaic Systems in Kenya: Methods and Measurement in Support of a Sustainable Commercial Solar Energy Industry	08/00	005/00
	The Kenya Portable Battery Pack Experience: Test Marketing an Alternative for Low-Income Rural Household Electrification	12/01	05/01
Malawi	Rural Energy and Institutional Development	04/05	069/05
Mali	Phase-Out of Leaded Gasoline in Oil Importing Countries of Sub-Saharan Africa: The Case of Mali - Action Plan. (French)	12/03	041/03
Mauritania	Phase-Out of Leaded Gasoline in Oil Importing Countries of Sub-Saharan Africa: The Case of Mauritania - Action Plan. (French)	12/03	040/03
Nigeria	Phase-Out of Leaded Gasoline in Nigeria	11/02	029/02
	Nigerian LP Gas Sector Improvement Study	03/04	056/04
	Taxation and State Participation in Nigeria's Oil and Gas Sector	08/04	057/04
Regional	Second Steering Committee: The Road Ahead. Clean Air Initiative In Sub-Saharan African Cities. Paris, March 13-14, 2003.	12/03	045/03
	Lead Elimination from Gasoline in Sub-Saharan Africa. Sub-regional Conference of the West-Africa group. Dakar, Senegal March 26-27, 2002 (French only)	12/03	046/03
	1998-2002 Progress Report. The World Bank Clean Air Initiative in Sub-Saharan African Cities. Working Paper #10 (Clean Air Initiative/ESMAP)	02/02	048/04
	Landfill Gas Capture Opportunity in Sub Saharan Africa	06/05	074/05
Senegal	Regional Conference on the Phase-Out of Leaded Gasoline in Sub-Saharan Africa	03/02	022/02
	Elimination du Plomb dans I'Essence en Afrique Sub-Saharienne Conference Sous Regionales du Groupe Afrique de I'Quest. Dakar, Senegal. March 26-27, 2002.	12/03	046/03
	Alleviating Fuel Adulteration Practices in the Downstream Oil Sector in Senegal	09/05	079/05

Region/Country	*Activity/Report Title*	*Date*	*Number*
South Africa	South Africa Workshop: People's Power Workshop.	12/04	064/04
Swaziland	Solar Electrification Program 2001—2010: Phase 1: 2001—2002 (Solar Energy in the Pilot Area)	12/01	019/01
Tanzania	Mini Hydropower Development Case Studies on the Malagarasi, Muhuwesi, and Kikuletwa Rivers Volumes I, II, and III	04/02	024/02
	Phase-Out of Leaded Gasoline in Oil Importing Countries of Sub-Saharan Africa: The Case of Tanzania - Action Plan.	12/03	039/03
Uganda	Report on the Uganda Power Sector Reform and Regulation Strategy Workshop	08/00	004/00
	WEST AFRICA (AFR)		
Regional	Market Development	12/01	017/01
	EAST ASIA AND PACIFIC (EAP)		
Cambodia	Efficiency Improvement for Commercialization of the Power Sector	10/02	031/02
	TA For Capacity Building of the Electricity Authority	09/05	076/05
China	Assessing Markets for Renewable Energy in Rural Areas of Northwestern China	08/00	003/00
	Technology Assessment of Clean Coal Technologies for China Volume I—Electric Power Production	05/01	011/01
	Technology Assessment of Clean Coal Technologies for China Volume II—Environmental and Energy Efficiency Improvements for Non-power Uses of Coal	05/01	011/01
	Technology Assessment of Clean Coal Technologies for China Volume III—Environmental Compliance in the Energy Sector: Methodological Approach and Least-Cost Strategies	12/01	011/01
Philippines	Rural Electrification Regulation Framework. (CD Only).	10/05	080/05
Thailand	DSM in Thailand: A Case Study	10/00	008/00
	Development of a Regional Power Market in the Greater Mekong Sub-Region (GMS)	12/01	015/01
Vietnam	Options for Renewable Energy in Vietnam	07/00	001/00
	Renewable Energy Action Plan	03/02	021/02
	Vietnam's Petroleum Sector: Technical Assistance for the Revision of the Existing Legal and Regulatory Framework	03/04	053/04
	SOUTH ASIA (SAS)		
Bangladesh	Workshop on Bangladesh Power Sector Reform	12/01	018/01
	Integrating Gender in Energy Provision: The Case of Bangladesh	04/04	054/04
	Opportunities for Women in Renewable Energy Technology Use In Bangladesh, Phase I	04/04	055/04

Region/Country	*Activity/Report Title*	*Date*	*Number*
	EUROPE AND CENTRAL ASIA (ECA)		
Russia	Russia Pipeline Oil Spill Study	03/03	034/03
Uzbekistan	Energy Efficiency in Urban Water Utilities in Central Asia	10/05	082/05
	MIDDLE EASTERN AND NORTH AFRICA REGION (MENA)		
Regional	Roundtable on Opportunities and Challenges in the Water, Sanitation And Power Sectors in the Middle East and North Africa Region. Summary Proceedings, May 26-28, 2003. Beit Mary, Lebanon. (CD)	02/04	049/04
	LATIN AMERICA AND THE CARIBBEAN REGION (LCR)		
Brazil	Background Study for a National Rural Electrification Strategy: Aiming for Universal Access	03/05	066/05
Bolivia	Country Program Phase II: Rural Energy and Energy Efficiency Report on Operational Activities	05/05	072/05
Chile	Desafíos de la Electrificación Rural	10/05	082/05
Ecuador	Programa de Entrenamiento a Representantes de Nacionalidades Amazónicas en Temas Hidrocarburíferos	08/02	025/02
Guatemala	Evaluation of Improved Stove Programs: Final Report of Project Case Studies	12/04	060/04
Mexico	Energy Policies and the Mexican Economy	01/04	047/04
Nicaragua	Aid-Memoir from the Rural Electrification Workshop (Spanish only)	03/03	030/04
	Sustainable Charcoal Production in the Chinandega Region	04/05	071/05
Regional	Regional Electricity Markets Interconnections — Phase I Identification of Issues for the Development of Regional Power Markets in South America	12/01	016/01
	Regional Electricity Markets Interconnections — Phase II Proposals to Facilitate Increased Energy Exchanges in South America	04/02	016/01
	Population, Energy and Environment Program (PEA) Comparative Analysis on the Distribution of Oil Rents (English and Spanish)	02/02	020/02
	Estudio Comparativo sobre la Distribución de la Renta Petrolera Estudio de Casos: Bolivia, Colombia, Ecuador y Perú	03/02	023/02
	Latin American and Caribbean Refinery Sector Development Report – Volumes I and II	08/02	026/02
	The Population, Energy and Environmental Program (EAP) (English and Spanish)	08/02	027/02
	Bank Experience in Non-energy Projects with Rural Electrification Components: A Review of Integration Issues in LCR	02/04	052/04
	Supporting Gender and Sustainable Energy Initiatives in Central America	12/04	061/04
	Energy from Landfill Gas for the LCR Region: Best Practice and Social Issues (CD Only)	01/05	065/05

Region/Country	Activity/Report Title	Date	Number

GLOBAL

	Impact of Power Sector Reform on the Poor: A Review of Issues and the Literature	07/00	002/00
	Best Practices for Sustainable Development of Micro Hydro Power in Developing Countries	08/00	006/00
	Mini-Grid Design Manual	09/00	007/00
	Photovoltaic Applications in Rural Areas of the Developing World	11/00	009/00
	Subsidies and Sustainable Rural Energy Services: Can we Create Incentives Without Distorting Markets?	12/00	010/00
	Sustainable Woodfuel Supplies from the Dry Tropical Woodlands	06/01	013/01
	Key Factors for Private Sector Investment in Power Distribution	08/01	014/01
	Cross-Border Oil and Gas Pipelines: Problems and Prospects	06/03	035/03
	Monitoring and Evaluation in Rural Electrification Projects: A Demand-Oriented Approach	07/03	037/03
	Household Energy Use in Developing Countries: A Multicountry Study	10/03	042/03
	Knowledge Exchange: Online Consultation and Project Profile from South Asia Practitioners Workshop. Colombo, Sri Lanka, June 2-4, 2003	12/03	043/03
	Energy & Environmental Health: A Literature Review and Recommendations	03/04	050/04
	Petroleum Revenue Management Workshop	03/04	051/04
	Developing Financial Intermediation Mechanisms for Energy Efficiency Projects – Focus on Banking Windows for Energy Efficiency	08/04	058/04
	Evaluation of ESMAP Regional Power Trade Portfolio (TAG Report)	12/04	059/04
	Gender in Sustainable Energy Regional Workshop Series: Mesoamerican Network on Gender in Sustainable Energy (GENES) Winrock and ESMAP	12/04	062/04
	Women in Mining Voices for a Change Conference (CD Only)	12/04	063/04
	Renewable Energy Potential in Selected Countries: Volume I: North Africa, Central Europe, and the Former Soviet Union, Volume II: Latin America	04/05	070/05
	Renewable Energy Toolkit Needs Assessment	08/05	077/05
	Portable Solar Photovoltaic Lanterns: Performance and Certification Specification and Type Approval	08/05	078/05
	Crude Oil Prices Differentials and Differences in Oil Qualities: A Statistical Analysis	10/05	081/05

Last report added to this list: ESMAP Technical Paper 083/05.