Paper No. 179

NEW CONCEPTS IN MODERN SIGNALLING MAINTENANCE METHODS

Wasif Roheel

B.Sc. Engg. (UEL), P. E. (PAK)

M.I.R.S.E. (UK) F.I.E. (PAK)

O.F.E.D.I. (WORLD BANK) M.C.I.T. (UK)

Deputy Chief Engineer/Signals (Modernization)

NEW CONCEPTS IN MODERN SIGNALLING MAINTENANCE METHODS

By

***ENGR. WASIF ROHEEL**

1. INTRODUCTION

1.1. Maintenance in general of any railway and especially of modern signalling equipment on the railway is a process to keep the system in safe and satisfactory functioning condition. Maintenance is and essential requirement of the system and may not be as allusive as design, manufacture an installation of the equipment. It is rather a process which is spreads over the entire life of the equipment before it is renewed. This is a task which needs continuous efforts with dedication to purpose and persistent attention by all staff involved in the process.

1.2. The first criteria of Signal Engineer should be that system is maintained perfectly and is safe and free of failures. Here Mr. H.W. Hadaway, Chief Signal Engineer (London) Transport can be quoted having said that All failures are preventable (AFAP). It is important that attitude of the maintenance Engineers should religiously be aligned with this motto, otherwise there is likelihood of increase in the failure rate with an ever increasing tendency of easy acceptance of failures. This concept may be an idle situation but the practical solutions are attainable keeping in view the essential limitations of such an achievement.

1.3. All failures need to be investigated within 24 hours by a responsible maintenance engineer to achieve AFAP motto. This postmortem could indicate the weak link in the system and the causes can be remedied to avoid future failures. For conventional signalling systems the need for adjustments could be easily detected or felt. Worn out pins, slack wheels, cranks and other ground gear can be checked and correction made therein.

1.4. With the Introduction of Modern Signalling concepts such as track circuits, colour light signals, point machines and other allied equipment, the task of maintenance has been complicated. The technical skill of the maintainer not only depends on his experience, but measuring instruments are needed to check the different characteristics of the system. It is now, an accepted fact that the person who maintains the equipment is a key figure and his qualifications and technical skill has a direct influence on the maintenance standards of the modern sophisticated equipment.

* *Deputy Chief Engineer/Signals (Modernisation).*

2. PHILOSOPHY OF MAINTENANCE

2.1. The philosophy of maintenance can be generally termed as "frequent examination of the equipment to check that it is free from damage, is clean and properly secured". There should also be a detailed examination at a specified interval of time to check full operation of the equipment. Signals can be tested as if these are properly clearing for each route and all change over relays are being correctly operated, lamp proving on all junction indicators and emergency replacement switch must be checked. For point machine the check can be the correct operation of clutch, over load protection and correct electrical tolerances in all contacts. Similarly, for other type of equipment regular tests are necessary to determine if the equipment is about to start deterioration in its condition.

2.2. The philosophy of maintenance can also be termed as making checks at regular intervals irrespective of the condition of the equipment, to determine its deterioration, damage or liable failure. On each visit the cleaning of the equipment can certainly provide a care against atmospheric conditions but major part of the time must be devoted to maintenance procedures.

3. LIMITATIONS

3.1. There are always limitations in establishing a perfect maintenance Organization and these limitations revolve round two major factors i.e. money and staff. Some time money is a major factor and on another occasion the non-availability of qualified staff. The staff requirement of a system can vary from one section of the Railway to another section which would be influenced by the number of trains and the size of the equipment installed on the section.

3.2. The inadequate funds available with the maintenance Organization pose a major difficulty on a developing railway system. It is not possible to have perfect inventory of all the spare parts needed to maintain a system. On a railway where the spare parts are normally imported, there is always shortage of some spares of the system, which forces a maintenance Engineer to adopt means which do not conform to an ideal maintenance standard, if this limitation remains for a longer time it give rise to the frequency of failures.

3.3. The diversity of the equipment design is also a major factor in limiting the technical know-how of the staff engaged for maintenance. There is a technological revolution going on in the world and every ten years new systems are evolved and brought into commission. No sooner the staff is conversant with one equipment then a new system is introduced with different technology.

3.4. The Railways of the developed countries also face troubles arising out of diversity of equipment supplied by different manufacturers of the signalling equipment. Different type of equipment places still more burden on the maintenance staff, as they have to master many techniques for maintaining the system properly.

The efforts should always be made to limit the systems to a few designs and to a few manufacturers. The ideal situation would be one standard design equipment from one or two manufacturers.

4. STAFFING

4.1. Staffing of a maintenance organization is the most important task of the maintenance Engineer. It has to be decided first what type of maintenance is to be carried out and based on the same the staff requirements, their qualifications and training etc. has to be assessed. It must be understood that the existing staff cannot cope with the increased work load if efficiency has to be expected of them but there is a normal tendency in the administrative and financial circles that the existing staff should be utilised for increased load of the additional systems. This not only brings in efficiency but can even endanger the safety of the travelling public, as adequate care can not be ensured for the safety equipment.

4.2. The maintenance staff required for a new project is normally calculated in the feasibility study of that Project and on its completion this staff must take up its responsibilities. This staff preferably be associated with construction of the project to gain adequate experience.

5. TRAINING

5.1. Training of staff and Engineers engaged in maintenance has assumed new dimensions with sophistication of equipment and Introduction of new technologies. The training can be sub-divided into the following :-

(a) Pre-service training.
(b) In service training.

5.2. Pre-service training

5.2.1. The concept of pre-service training in Signal Engineering is more important than any other field since this Engineering is not taught at any level of the educational Institutions. The persons recruited have knowledge of Electrical, Mechanical or Electronics only which need to be refined and they are made conversant with the principles of Signalling System. It is important that this training be planned in such a way that concepts of Signal Engineering maintenance are absolutely clear to all maintenance staff. They can further build up their knowledge during the service span and in fact a good signal engineer is really produced with experience and knowledge.

5.3. In service training

5.3.1. The pre-service training of maintenance staff might have been conducted thoroughly but with the passage of time is to be understood by the maintenance staff.

To keep the knowledge of maintenance Engineers uptodate refresher courses at all levels are necessary. These can be of short duration and as well as of long duration depending on the availability of time and the job requirements.

5.3.2. If the above two trainings are conducted with proper planning the maintenance staff and the Engineers would be well equipped with the techniques to maintain the system at best possible level.

6. STATISTICS AND DATA

6.1. To have an effective management control on the performance of signalling systems, it is essential to have proper record of the equipment and the frequency of its failures. This information has to be up dated on day-to-day, month to month and year to year basis and comparison made at regular intervals with the previous periods. The statistics of the present total installed units of equipment and to be installed units can give a fair idea of the failures which may be expected over the years.

6.2. The Signal engineers must be aware of the relative proportions to delay caused by the Signalling system and due to other causes. It is normally observed that major causes are not Engineering difficulties but is the failure of human element involved in the operation of the system. In order to eliminate the human element, as far as possible, the Signalling Systems could be designed but this would be achieved at a very high cost.

6.3. Consideration of the above fact gives a strong reminder to Engineers that expansion of Automatic Control Systems removes most of the manual Operations and has greater benefits not only in the reduction of labour costs but increase in safety and reduced detentions. While pursuing the automation it must be kept in mind that a proper balance has to be struck where cost and perfection can be balanced. It would be of no use if perfection is achieved at a cost which the travelling public cannot pay.

7. INSTALLATION STANDARDS

7.1. Required maintenance standards would be more difficult to achieve if the equipment has not been properly installed in the first place. This applies particularly, to the moving mechanism such as mechanical signalling and point-machines etc. Some of the faults may arise by not following the correct principles at the time of installation of equipment and proper care not being taken in fixing the cranks, rodding and their connections. Where there are abrupt changes in the direction of movement of rodding, smooth mechanical operation must be ensured which must have minimum wear and tear on the relevant gear. Weather conditions and temperatures also play a vital role and it does require proper design to ensure that these changes are compensated in the system.

7.2. All mechanically moving gears have a certain life and with the expiry of that life, renewal of the entire gear is necessary, which if not done at the correct time then there is bound to be maintenance problems and subsequent increase in signal failures. To remedy such a situation the general life of moving parts be assessed and all those systems and gears which have out-lived their life should be renewed completely. The maintenance staff must be given properly designed equipment for easy maintenance to keep the failures under control. What has been said above relates primarily to mechanical operation but this also applies to all other types of equipment.

8. PATTERN OF MAINTENANCE

8.1. The maintenance was historically started with carrying out Maintenance Procedures at site by the concerned staff. The frequency of the visits and actual occupancy of the time was the responsibility of the maintainer at site as the earlier equipment was Mechanical Type for which this procedure could be accepted. With the addition of more sophisticated equipment and application of Electrical and Electronic circuits this method of maintenance cannot be relied upon.

8.2. For Modern Signalling Equipment a schedule of maintenance has to be determined indicating the extent of work which the maintainer has to perform on his normal visit at the site. On each such visit he must inspect the equipment to determine if it is functioning correctly. The voltage and current readings at different critical Junctions of the systems need to be checked if these are within the laid down parameters. It must also be obligatory for the supervisory staff and the Engineers to visit and check the equipment at regular intervals so as to determine the conditions of equipment and the standard of maintenance. With the increase complexity of the signalling system, the design of the equipment and overhauling methods have to be improved to reduce the need of highly skilled staff at the site.

8.3. The maintenance can be generally carried out under three Heads :-

(a) Corrective maintenance.
(b) Preventive maintenance, and
(c) Overhauling of equipment.

8.3.1. Corrective maintenance

With fast increasing modern signalling systems and high speed traffic, corrective maintenance has assumed new dimensions. With the Introduction of Electrical and Electronic Systems the failures can be sudden and at rendum. Most of this type of equipment can not be visually inspected nor gives warning before failure. The repair is often not easy at site. It is more convenient to replace a card or a group of relays or the relevant part which has developed fault. The repair at site should be quick and staff should be well qualified to deal with such a situation.

8.3.2. For conventional electrical and mechanical signalling equipment the repairs has to be carried out at site as replacement is some time not possible. The staff should have all the necessary tools and plants to deal with such situation and with the invention of modern tools this task can be made easier for the maintenance staff.

8.4. Preventive maintenance

8.4.1. This aspect of the maintenance is most important as major portion of maintenance work consists of preventive maintenance i.e. well defined work in time scale with maximum availability of the equipment for use. Both No; of train operations and atmosphere environment have a great influence on the working of the equipment and thus on preventive maintenance methods. A time limit needs to be set during which a technician/maintainer has to check the equipment according to pre-determined schedule of maintenance to avoid possible failures.

8.4.2. The work load of each maintainer must be calculated on yearly basis catering for preventive maintenance concept. If the criteria of calculating work load is not properly employed then the staff requirements would not be sufficient for carrying out such type of maintenance.

8.4.3. The preventive maintenance can be made more effective if adequate checks and necessary supervision is involved in the process. There must be some feed back to the maintenance engineer which should indicate that the maintenance according to laid standards is being carried out at site. The correctly planned preventive maintenance contributes to longer life of the equipment and less failures.

8.5. Overhauling

8.5.1. The 3rd part of the maintenance is overhauling of the equipment after a specified time period. With the No. of operations the gear gets certain amount of wear and tear and the replacement of the equipment or its part is necessary to keep the tolerances of the dimensions within the permissible limits. The correct overhauling of the equipment can only be carried out in well equipped workshops or factories.

2

8.5.2. Some of the parts can be overhauled at site which do not have any moving part or are equipped with very few moving parts. Colour light signals can be a good example of this. The equipment such as relay and point machines cannot be overhauled at site. Therefore, these are to be removed to environments where proper tools, gadgets and testing equipment is available for overhauling and final testing.

8.5.3. In Workshop or a testing laboratory under controlled conditions all parts are first checked and tested if these are within the permissible tolerances, if not these are replaced. The entire assembly is again checked and tested according to the specifications and certified as fit to be used at site. The equipment thus overhauled can again give approximately 80% of the life of a new part.

9. FAILURES ANALYSIS

9.1 One of the essential part of the duties of the maintenance staff is to attend to failures by quickest means to rectify the faulty equipment. On section where dense traffic is being handles one prolonged failure may disturb the entire pattern of traffic. Although Rules and procedures permit the traffic to be handled in such a situation but any failure may effect the schedule of trains specially on a section where the trains are running in batteries. It is essential that adequate communication facilities are available to inform the maintenance staff for the rectification of fault and staff has necessary conveyance to reach the site urgently. The fault is rectified at site and the investigation of its real cause is subsequently carried out by the Supervisory Staff.

9.2 To achieve desired punctuality of train the position prevailing on the entire system is generally checked every 24 hours. Daily Punctuality Bulletin giving the causes of detention to trains in the last 24 hours needs to be issued by the Operating branch for the information and remedical action by different departments. Picked up from this statement the attributed Signal and Telecommunication failures are to be analysed with the help of Divisions/Maintenance centres to arrive at the correct cause of each failure. Failure of a signal is the final act of an unknown cause which can be different in each case, such as, failure of human element, mis-manipulation of Signalling equipment, long duration of electrical power failures, Drivers losing token, inadequate ballast, non-standard and damaged sleepers, defective drainage of yard, breakage of bond wire, creep in yard, telephone and telegraph overhead lines defective, signalling and telecommunication equipment failures and out side interference such as tress passing etc. Any of this cause can trigger a Signal failure.

9.3 During the last few years an effort has been made to maintain statistics by the Signal Branch of Pakistan Railways after investigation of the signalling failures on monthly basis. Annexure 'A' elaborates the figures from October, 1988 to June, 1989. During this period 3053 signal failures said to have contributed to late running of trains. After proper investigations of these failures, the picture emerged is shown in Figure-I.

SIGNAL ENGG : DEPTT :	14.96%
OPERATING DEPTT :	36.55%
CIVIL ENGG : DEPTT :	10.51%
ELEC : ENGG : DEPTT :	6.48%
MECH : ENGG : DEPTT :	0.58%
TELECOM DEPTT :	0.52%
T & T DEPTT :	8.28%
OTHER CAUSES	22.07%

9.4 The figure above shows that Signal Branch was responsible for only 14.96% of the total failures attributed to them. The Operating Branch has caused 36.55% of the total failures including wrong booking of signal failures. The Telephone and Telegraph Department's overhead lines have contributed 8.28% Electrical Power failures have contributed 6.48% and P.Way has contributed 10.51% to the failures. The failures caused by out side interference are 22.07% and others are indicated in Annexure-'A'. This percentage analysis elaborates a picture wherein contribution to signal failures by different branches can be seen in terms or number of failures.

9.5 The second analysis carried out is indicated in Annexure-'B'. The failures are divided into different types and are shown against different departments, who were responsible for those failures. This analysis can further elaborate the areas where efforts can be intensified by various disciplines of Railways to reduce signal failures on their account.

9.6 The analysis mentioned here are the basic ones and based on the same many more can be carried out. A Division may analyse station-wise position and pin-point the station which has the maximum failures over a specified period. On each station the failures can be sub-divided into different categories and if properly watched over a period it will indicate the real cause. The exact area of trouble can then be tackled to eliminate such type of failures in future by preventive maintenance methods.

10. CONCLUSION

10.1 It has been endeavoured in this paper to give a review of the philosophy and other essential of modern concepts in signalling equipment maintenance. Efforts must be directed by all to implement well planned preventive maintenance procedures which would make the system less liable to failures. Some light has also been thrown on the contribution of other branches to signal failures. Efforts are, therefore, necessary by each discipline of railway to reduce their contributions to the signal failures.

10.2 Now that Pakistan Railways is entering into a new era of Telecommunication advancement the computer availability can further prove beneficial in assessing the correct causes of signal failures and it is hoped that this paper would provide some food for thought to all concerned, to devise ways and means for improving the maintenance standards.

BIBLIOGRAPHY

1. 'Fail-safe' By H. W. HADAWAY PROC. I.R.S.E. 1966/67.
2. Notes on Duel Maintenance by B.O. Baldwin PROC I.R.S.E. 1951.
3. Maintenance of Signalling and Telecommunication on S.N.C.F. by R.SAVARZEIX, PROC. I.R.S.E. 1976.
4. Maintenance of a Modern Railway with particular reference to Signalling By R.G. BATES, PROC. I.R.S.E. 1975.
5. Maintenance of the Railway Signalling System on London Transport By H.W. HADAWAY PROC. I.R.S.E. 1976.

APPENDIX-'B'

STATEMENT SHOWING DIFFERENT TYPES OF FAILURES WITH CAUSES DULY ATTRIBUTED TO DIFFERENT BRANCHES.

			OCT 88	NOV 88	DEC 88	JAN 89	FEB 89	MAR 89	APRIL 89	MAY 89	JUNE 89	REMARKS
1.	ADVANCE STARTER RAISED OR PLC ISSUED.	SIG	11	10	8	17	12	18	23	70	64	
		TFC	30	20	24	70	42	51	86	171	116	
		ELECT	3	1	7	8	–	5	11	37	57	
		T & T	10	11	12	11	17	23	28	51	86	
		ENGG.	1	1	3	8	5	–	3	15	25	
		MECH.	1	–	2	–	–	–	1	2	5	
		TELECOM	–	–	–	1	–	1	5	4	4	
2.	HOME OR OUTER SIGNAL DEFECTIVE.	SIG	9	12	17	18	9	35	32	45	41	
		TFC	23	26	42	35	23	58	71	113	103	
		ELEC	4	2	4	4	2	7	–	18	26	
		T & T	–	–	–	2	–	–	1	–	1	
		ENGG.	14	15	12	22	2	17	27	77	69	
		MECH	1	–	–	–	–	–	2	3	–	
3.	FAILURES ON KC-LND SECTION.	SIG	–	–	–	1	–	–	1	2	2	
		TFC	–	–	–	1	3	1	3	2	2	
		ELEC	–	–	–	–	1	–	–	–	–	
		T & T	–	–	–	–	–	–	–	–	–	
		ENGG	–	–	–	1	–	2	–	1	1	
		MECH.	–	–	–	1	–	–	–	–	–	
		O/C	1	–	–	–	–	–	–	–	–	
4.	OTHER CAUSES/ OUTSIDE INTER-REFERENCE	TELECOM	–	–	–	–	–	1	–	–	–	
			45	33	57	70	44	69	46	102	207	
	GRAND TOTAL.		153	131	188	270	160	288	340	713	810	

Paper No. 180

MAINTENANCE OF DRAINAGE SYSTEMS

Engr. S. Mansoob Ali Zaidi
Chief Construction Engineer, CRBC-II, Project, D.I. Khan.
Engr. Haroon Shami
Assistant Professor, University of Engg. & Technology, Lahore
Engr. Muhammad Mehdi Zaidi
Assistant Design Engineer, I&P Deptt. Lahore.

MAINTENANCE OF DRAINAGE SYSTEMS

By

***ENGR. MANSOOB ALI ZAIDI**
****ENGR. HAROON SHAMI**
*****ENGR. MUHAMMAD MEHDI ZAIDI**

SYNOPSIS

In developing countries like Pakistan, the developmental activities comprise mainly of construction projects, majority of which are in the domain of civil engineering. A substantial chunk of our development budget is used in the construction of new civil engineering projects. With the increase in the number of completed projects the need for maintenance efforts also increases, but somehow these efforts are very much below the required level if not absent altogether.

This situation can be attributed to the tendency of the financial planners to restrict the maintenance funds to levels much lower than the minimum needed, even with the increase in the requirements, the absence of research and inadequacy of new thoughts in maintenance methodology and techniques. The results are obvious.

In the drainage senario, specially the surface drain systems, the need for proper and regular maintenance is vital. A surface drain, how-so-ever well designed and constructed will, without proper and regular maintenance, generally be rendered into a marshy strip, full of weeds, thus losing its utility almost altogether and the restoration of its functional capacity may require complete re-excavation of its prism.

This paper presents a brief resume of the state of the art in maintenance of the drainage projects/systems, the problems and dilemma of a maintenance engineer with special reference to a typical system/area and finally the conclusions drawn by the authors.

INTRODUCTION

Agriculture is the main occupation of the people of Pakistan and the back bone of the national economy. The maximum contribution comes from Irrigated Agriculture, which requires irrigation water as the prime input. Application of Irrigation Water over the years causes waterlogging, the rate and extent depending upon the quantity of applied water, soil drainability, and climate of the area. This waterlogging has to be

* Chief Construction Engineer, CRBC-II Project, D.I. Khan.
** Assistant Professor, University of Engg. & Technology, Lahore.
*** Assistant Design Engineer, I&P Deptt. Lahore.

eliminated in order to maintain and improve the crop yields, through drainage of the affected areas by anyone or a combination of more than one of the following remedial systems.

(a) Surface Drains
(b) Subsurface Drains

  (i) Tile drains (Horizontal Drainage)
  (ii) Drainage Wells (Vertical Drainage)

Surface drains though they have a limited role in lowering the subsoil water level, are the cheapest and most effective mode for drainage of stagnating surface waters or effluents from tubewells and tile drainage sumps and thus form a major part of our drainage efforts. The length of surface drains in the province of Punjab alone is about 4,000 canal miles and requires the maximum maintenance efforts.

IMPORTANCE OF MAINTENANCE OF DRAINAGE SYSTEMS

The drainage systems are instrumental in seasonal removal of water necessitated due to build up of water-logging and rise of subsoil water table to the root zone of crops sown in the area. The system involved may be an essential part of an irrigation system in an arid or semi arid area or one of the larger and more extensive systems located in the semihumid or humid areas.

As mentioned earlier there are three types of drainage systems :

(1) open or ditch;
(2) subsurface or buried pipe;
(3) drainage well.

Each system has its unique maintenance problems. even an adequately designed and well constructed drainage system specially a surface drainage system will surely fail if proper and regular maintenance is absent. Sporaidic efforts can only keep the system alive but in a sick and ineffective condition. Recently, the drainage of agricultural lands has assumed new importance as a means of increasing crop yields, reducing the risk involved in the crop production enterprise, and ecological/environmental health improvement. The price of drainage improvements is rising more slowly than the price of land. This encourages investments in drainage system improvements and maintenance.

Framji (1984), in his address to the 12th Congress of the ICID (International Commission on Irrigation and Drainage) stated, "Drainage is one of the most critical requirements on which the management of land and water resources and maintenance of irrigated agriculture depend. With good drainage, even the worst irrigation farmer cannot easily ruin his land; with inadequate drainage, even the best farmer cannot easily save it or ensure his crops".

Timely performance of preventive and regular maintenance of drainage systems is absolutely necessary if the systems are to perform the functions for which they are designed and built. Unfortunately, the importance of timely maintenance is often overlooked, resulting in the requirement of additional expenditure for repair of the damages caused by deferred maintenance.

MAINTENANCE OBJECTIVES

The objectives for maintenance of a drainage system should mainly be to :

(1) keep the system in top operating condition at all times through proper maintenance;

(2) obtain the longest life and greatest use of the system facilities by providing adequate maintenance and replacement; and

(3) achieve the foregoing objectives at the lowest possible cost.

Maintenance activity begins the day the systems is placed in operation, or under some circumstances, before construction of a system is completed and the system as a whole is placed in operation. Keeping maintenance work current on all faclities in a system is a keystone to any successful drainage system. Preventive maintenance not only pays dividends in economical operation; a smooth-working system means uninterrupted removal of the unwanted, problem waters at a lower cost.

All structures and facilities of a drainage system are subject to deterioration in varying degrees. Constant vigilance is necessary to be alert and correct potentially unsafe or unsatisfactory conditions as they develop. The control of weeds and pests, storm erosion of contiguous lands, banks and bottoms, aggradation, degradation and embayments are the problems that must be given due attention. Frequently the latter are more time consuming and costly over the years. Both surface and subsurface drains have to be kept clear and working at all times.

Maladies and Remedies

The most common agents of deterioration and ultimate failure of a surface drainage channel/system are sedimentation, caving-in of slopes, Bank erosion, and aquatic and terrestrial weeds and plants infestation. The causes giving birth to these maladies, their growth, and methods of control are explained and discussed in the following paragraphs :

1. Sedimentation

Sediment deposition in a surface drain and consequent aggradation are caused by the sediments in excess of carrying capacity entering the channel prism through overland flow which brings with it the eroded soil load, and the sloughing/caving prism slopes. Sediment problem is more common and serious in alluvial plains with barren/fallow areas flanking the drain.

The remedial measures that may prove to be effective are :

(a) Providing the steepest possible slope to achieve maximum silt carrying capacity. In alluvial plains, either the land is too flat or slope is to be restricted for controlling bed scour and bank erosion.

(b) Desilting at regular intervals as the need arises. This is a costly alternative and is in fact a short term solution, but has to be resorted to in view of its simplicity of execution and availability of necesary equipment and plant.

(c) Stopping the overall overland flow by constructing substantially high containing banks and providing proper inlets to let the run off enter the drain at suitable predetermined locations.

(d) Provision of settling basins for trapping the bed load and a part of the suspended silt to save the drain prism on the D/S; but such traps if used need a sufficient area and regular evacuation of the trapped sediment. Normally in irrigated/cropped areas such basins may not be feasible on account of non-availability of land and the disposal of the accumulation of evacuated material which keeps on piling up as the cleanings progress over the years.

(e) In rolling or hilly terrain, terracing and provision of check drains running almost on the contour are also helpful in checking the entry of excessive sediment into the drain prism.

(f) Stabilisation of prism slopes and turfing of banks slopes in some selected areas will also help by eliminatng the possibility of sedimentation due to sloughing/caving-in- of the slopes/banks.

(g) Preventing pollution and dumping of sullage and industrial waste in the drain

In our country, the first three remedies at a, b, & c above are employed.

2. Caving in/Sloughing of the Prism Slopes

The common causes for this phenomenon are erosion and unstable side slopes which have not been designed to fit in with the character of the local soil. The erosion can be mitigated by adjusting the longitudinal slope of the drain or providing protective measures like pitching which has to be permeable.

In case the prism slopes are too steep for the soil they are made of, the sloughing can be arrested by :-

(i) Flattening the slopes.
(ii) Providing a blended soil cover i.e. replace the slope soil to control the pore pressures and consequent sloughing.
(iii) Stabilising the slope soil.
(iv) Providing stone protection underlain with Geo-textiles.
(v) Providing permeable fascine or bushing protection.
(vi) Providng stout revetment or rip-rap specially in curve reaches.

In a given location the choice of an appropriate remedial measure, will involve a detailed consideration of site conditions.

Generally speaking the flattening of side slopes is by far the cheapest and easiest mode and thus will more often than not, be the most appropriate solution. However, experience thas shown hat usually, it is wiser to accept extra trouble and expense to construct the drains in the first place with smooth and dressed side slopes in undisturbed soil, flat enough to promise reasonable assurance of built in stability and durability.

3. Deterioration of Banks

Drain Banks like other embankments are prone to damage by rain, wind and parallel flow of run-off alongside. Bank protection is provided through steps to eliminate or reduce the parallel flow, like small crossbunds called teeth or spreading the run off by provision of adequate number of inlets at suitable intervals. The damage caused in the form of lost earthwork through rain, wind or flow erosion has to be replaced periodically or as needed. In high rainfall areas or erodible soils, grass cover or other stabilising methods like revetments may be used on slopes.

4. Weeds and Plants

Weeds and self propagating plants both aquatic and terrestrial cause operational adversities. The terrestrial species affect the banks and land strips alongside, while the aquatic varieties, floating, rooted, emersed or submersed obliterate and choke the drain prism reducing its capacity, sometimes to absolute nothingness by choking the drain section solid, through their own bulk, embedded in sediments depositing due to diminishing velocities. Clearance of drain section after it has choked completely is very cumbersome and expensive.

It is therefore always essential to remove, destroy and control the weeds before they get too thick or congested. If this worst malady that befalls almost all surface drains, is controlled at the proper stage and time, the drains can be kept in reasonable operating condition providing envisaged benefits to the service areas.

(a) Plant and Weed Types and Characteristics

The number of types/species of plants and weeds identitied from growth on drains is very large, and mention of all of them is beyond the scope of this paper. Broadly speaking these can be classified as below :

a) Classification Categories

   (i) Grasses
   (ii) Broad leaf plants.

b) Plant Groupings

   (i) Annuals (Winter & Summer)
   (ii) Biennials
   (iii) Perennials (Simple and creepers)

Most common aquatic plants behave as perennials, though some are not true perennials, and can be divided into vascular (macrophytes) and non-vascular (Algae) types.

The aquatic plants can, according to growth characteristics, be grouped as below :-

(i) Emersed plants are rooted to the bed and develope structures that grow standing above the water surface, e.g. cattails, rushes, sedges, watercress etc.

(ii) Submersed plants grow wholly under water but stalks may reach the surface and bloom above water surface. They may or may not berooted in the bed. If unrooted, they grow freely, buoyed by air cells in the leaves and stems. Samples are, the true pondweeds, hydrilla, watermillfoils and many more;

(iii) Floating plants can be considered as akin to submersed type in so much that they are not rooted and also grow freely in the water in a floating posture e.g. water hyacinth and duckweed etc.

(iv) *Mosses* :- True mosses belong to the phyllum Bryophyta family, and are more akin to filamentous Green Algae as compared to true flowering plants.

Weeds

The simplest definition of a weed is that, "It is an out of the place plant, that is very competitive to the deteriment of more desirable vegetation and can seldom be put to any useful application." Weeds are most of the time a potent nuisance. Weeds may be of terrestrial or aquatic habitat. In choking the drains, aquatic weeds play the devil.

Examples of such weeds are, hydrilla (hyd, Verticillata Royle) Eurasian watermilfoil (Myriophyllum) true pondweed (potamogeton), Waterhyacinth, Water weed (Elodea), Coontail, Algae (Green and Blue green), Aligatorweed and mosses etc.

Our surface drains are infested, mostly by hydrailla, pondweed, water hyacinth, watermilfoil, and Algae, which cause serious problems of flow and choking.

Some terrestrial weeds that grow and thrive on waterline on channel prism slopes also create obstrction to flow and assist other aquatic families in causing choking of the Section.

Methods for Control of Problem Plants & Weeds

The main main Weed Control Systems generally employed on surface drains are :-

(a) Mechanical,
(b) Biological and
(c) Chemical

Mechanical Control, comprises, methods that envisage physical cutting or pulling out and removal, manually or with machines.

(a) Manual cleaning requires pulling out with metal hooks attached at the end of a long pole or rod. This is a very slow operation and gives a temporary relief which usually lasts only for a few weeks. This method is also hazardous to the health of the workers due to toxicity of some of the weeds and infestation of drain section by the leaches and other aquatic insects. However, this is the simplest, easiest, and most of the time the cheapest too, and that is why it is widely used.

(b) Chains and chain screens pulled by farm tractors or other vehicles are also employed to remove the weeds, specially the floating and submersed types, like floating water-hyacinth, hydrilla, pondweed and Algae. This method though speedier than manual also provides a temporary relief as it simply removes the foliage and superstructure of emersed plants and attached weeds.

(c) Weed cutting machines mounted on boats and excavator booms can cut the weeds under water but leave them in the drain prism necessitating a second operation for removal at an enhanced cost.

(d) In case of heavily infested or chocked sections, Draglines or excavators are used to clean the section. These machines can do a good job though at a somewhat higher cost.

In all the above cases, the removal of evacuated stuff is an additional burden.

Biological Control

Biological control involves the utilisation of natural antiweed/weed consuming elements such as predators, parasites, aquatic animals and pathogens in reducing the population and growth of weeds and their allied organisms. In the recent past some successes have been achieved with the introduction of some insects and fish to control aquatic and terrestrial weeds and plants.

One of the Carp fish of Chinese origin called Chinese Grass Carp, is reputed to be capable of consuming several times its body weight of vegetation per day. This fish was introduced to Pakistani waters in early sixties and breeded well, but its utilisation in our surface drains till this day remains only a paper possibility as the conditions in our drains are detrimental to the very existance of fish what to say of growth. The main anti-fish conditions are :-

(i) Toxicity caused by pollution and dumping of sullage and industrial waste including acids.

(ii) Some of the drains are rendered just marshy strips/ditches during low run-off winter period.

(iii) Disposal of saline effluent from drainage tubewells in saline areas into some of the drains.

(iv) Apprehension of loss, in case the fish population introduced, is destroyed.

However, this useful fish does deserve trial in isolated non-saline, non polluted, perennial reaches of some of the surface drains.

In California (U.S.A.), a tiny white moth of Pakistani origin has been introduced on trial to detemine its ability to control "Russian Thistle" a serious menace. The moth is proving to be specific in what it attacks.

Chemical Control

Mechanical methods for control of water weeds involve heavy work and in most cases do not eliminate the weeds permanently. Studies have resulted in the development of chemical treatments which kill the weeds and leave them in a condition to be permanently disposed off either by disintegration or by physical removal. Water weeds killed by chemicals usually sink to the bottom. If the weeds accumulate and cause clogging, they will have to be removed from time to time by mechanical means.

A very large number of Chemical agents that effectively control weeds are in use in developed countries. The spectrum of activity of a chemical and other conditions of use alongwith the knowledge of the most vulnerable period/stage in the life cycle of a weed and climatic factors determine the type, time and dosage of application of a specific herbicide. The herbicides in general are very toxic to animals and man, and can therefore create environmental problems. Their use, therefore warrants that the user must have a thorough knowledge of weeds life cycle and pathology, alongwith the composition and properties of the herbicides with reference to both weeds and animals alongwith humans. In addition, the interaction of herbicides with soils is also to be kept in view. This is the "Pest Manager" concept adopted by the developed countries where the herbicides are used widely and handled only by properly qualified and equipped individuals. The IPM (Intergrated Pest Management) Technology is rapidly developing and picking up acceptability.

A brief introduction to some most commonly used herbicides is presented in the following paragraphs :

(i) Herbicides for submersed and floating weeds alongwith Algae are Acrolein, copper sulphate pentahydrate, Diquat-Dibromide, Endothall and Xylene (Grade-B).

Copper sulphate has an established potable water tolerance of 1 p.p.m. and can safely be used in almost all locations with the exceptions of a few, but the antiweed effectiveness is also low at this concentration which requires a prolonged applicatioin period.

The other chemicals mentioned supra are more effective but more toxic also and have to be used with care and caution, where the need is established. Xylene (Dimethyl Benzene) is however less toxic at lower dosages.

(ii) Herbicides usually found effective against emersed weeds like Cattails, Bull rushes, Phragmites and Giant Reed etc. are, Amino-Triazole, Dalapon, Diquat, 2,4-D, Glyphosate (Round up & Rodeo) and TCA.

Glyphosate has many uses and can also be used in weeds in dried up drains but needs care in handling. Dalapon & 2-4-D are some what less toxic but have lesser application range or need a higher dosage and sometimes repetition as well.

(iii) Mononuron and Diuron are effective for control of terrestrial weeds in dry channels. Toxicity not yet determined.

(iv) Herbicides, like weed oil, Dimethylamine, Dalapon, Glyphosate, Ammonium Sulphamate and Atrazine etc. are effective for the control of terrestrial weeds infesting the banks of Drainaage and Irrigation channels.

Chemical control, though a scientific method and almost sure in action, is a very expensive option, and can hardly be resorted to in the face of financial stringencies, so common in the Developing countries like ours.

Sub-Surface Drains (Tile Drains)

Tile drains though introduced in the sixties could not attract general application due to high installation cost. However, in the past 15 years four major tile drainage projects have been put into execution. One out of these, the Khairpur pilot project is functioning for the last several years now; the other three in Mardan, Faisalabad and D.I. Khan are under construction.

Tile drain systems, if laid properly and maintained regularly give trouble free service for long periods.

The maintenance requirements of tile drain systems, though few and only occasional, need systematic approach for timely identification and fulfillment of the maintenance needs which require special equipment.

The main cause for the failure of a tile drain is deterioration both in physical and hydraulic parameters precipitated by the following :-

(i) Silting/mineral deposits are caused either by settlement of mineral salts or failure of gravel pack or damaged pipe.

(ii) Incrustation may be caused by certain salts depositing and choking the scree holes.

(iii) *Clogging of screen/gravel pack.*
This can happen due to salts or migration of fine particles of the soil from surrounding soil.

(iv) Algae or Pipe Mosses
They are generally formed in the drains which do not run full bore or with low velicities.

(v) Vegetation roots can enter the tile if water searching plants are grown in the vicinity of tile in semi arid areas.

(vi) *Broken Pipes*
The drain pipes can get broken in exceptional cases like heavy loads passing over the trench before the soil over drain pipe has consolidated.

(vii) Location of outlet pipe with reference to water level in the carrier channel.

If the outlet pipe gets submerged in the carrier channel, it can become clogged with trash and silt.

Identification of Repair Needs

If the drain behaviour differs from the designed objectives, a detailed inspection of the drain lines will provide conclusions about the needed maintenance as under :

(i) The absence of a water table and no increase in the drain flow after a rain or irrigation may indicate that the water did not soak into the soil to the depth of the drains.

(ii) A high water table after rain or irrigation that does not decline in a few days indicates the drain may be either clogged or sealed, or the space between drain lines may be too wide for the type of soil.

(iii) Drain lines that do not flow and a high water table directly over the drain lines indicate clogged lines or sealed screen holes.

(iv) If the drain is full of water and the water table in the soil is above the drain, a plugged or overloaded drain is indicated.

The cost of excavation to inspect the drains can be saved if the above observations indicate the system is in good operating condition. However, if the observations indicate the drain system is clogged or sealed, it should be excavated for visual inspection and diagnosis.

Cleaning of tile drains

The tile drains are usually cleaned by :

(i) Water jet
(ii) Sulphur dioxide

(i) Water jet cleaning is effective for many clogging and sealing problems. High-pressure jetting equipment, such as contractors use for cleaning sewers, utilizes the extreme cutting action of water jets to dislodge and move obstructions. Jets of water exiting at various angles from special cleaning nozzles can dislodged deposits of silt or minerals and cut roots that may be present. Water from jets on the rear of the nozzle washes the dislodged material out of the drain and propels the nozzle and the nose up the inside of the drain pipe.

Two types of nozzles are commonly used to clean tile drain pipes. They are cleaning nozzles and penetrator nozzles. The cleaning nozzle is effective for removing silt, small roots, and soft mineral deposits from the drain pipe. The penetractor nozzle is required to break through dense silt or mineral deposits and heavy root masses.

Ordinarily, a cleaning nozzle does not have a forward jet as does a penetrator nozzle. A cleaning nozzle has five jets located around the circumference at mid-nozzle and placed at a 90 degree angle to the longitudnal axis, (fig. 1-A). These jets scour the interior surfaces of the pipe as well as the joints and openings. Five additional jets are located around the rear of the nozzle and placed at a 30 degree angle to the longitudinal axis.

The purpose of the rear jets on a cleaning nozzle is to propel the nozzle forward, to create high turbulence within the drain, and to provide sufficient water to keep material floating until it reaches an opening in the drain where it can be removed by a dewatering pump. Dewatering pumps can pump water, slurry, and material suspended in the water. They are the types used by waterworks repair crews to remove mud and water from excavations made to repair broken waste lines.

If the cleaning nozzle cannot dislodge the material plugging the drain pipes, a penetrator nozzle must be used. A penetrator nozzle has five rear jets placed at a 15 degree angle to the longitudinal axis (fig. 1-B). The low jet angle gives it the additional forward thrust needed to penetrate accumulations of roots and silt, which may be clogging the drain. This nozzle also has a jet in its nose that can disrupt deposits and cut through accumulations of roots. The penetrator nozzle can remove roots plugs and cut roots upto one quarter inch in diameter.

Root plugs are caused by small dead roots that break off and lodge at a single location such as a rough joint or a junction. Live roots may develop in a large mass in the drain and seriously impede water flow. The roots of trees and shrubs may grow into drain pipes in sufficient quantity to clog them.

Sulfur Dioxide Cleaning

Drain systems found to be affected primarily by mineral man-ganese or iron deposits, but with little or no silt and few or no roots present, can be cleaned chemically by injecting a 2-percent solution of sulfur dioxide (SO_2) gas and water. Whe iron is deposited in combination with organic matter, sulfur dioxide cleaning may not be fully effective. Cleaning with sulphur Dioxide gas requires care and caution as the gas is a hazardous material.

The principal health hazards from sulfur dioxide are breathing excessive quantities of fumes or burning the eyes or skin with the liquid. The gas is intensely irritating to the eyes, throat, and upper respiratory system.

Information on necessary precautions can be obtained from the gas supplier. A gas mask should always be used when entering partially closed or completely closed areas such as a sump or manhole.

DEVELOPMENT OF MAINTENANCE PROGRAMS

Obtaining the longest life and greatest use of drainage facilities can best be accomplished by providing good maintenance and a programme of systematic improvements and replacements. In many instances, it is hard to determine the point at which good maintenance ends and replacement begins.

As drainage works advance in age, a programme to replace worn out and obsolete structures is essential to extend the useful life of the system. Improvements or betterments such as additional control structures will provide for better service and extend the system's period of usefulness.

The key to good maintenance is frequent inspection. Although this applies to many situations, it is especially important in the care and maintenance of drainage systems. Inspection followed by proper care will avoid major maintenance later. Proper maintenance demands close and continuous examination of system facilities by experienced personnel followed by timely repair and replacement programmes. Maintaining a system in a structurally sound and functional condition can be accomplished only by repair and replacement throughout its life.

Operation and maintenance instructions and criteria

A detailed manual for operation and maintenance on major structures should be prepared covering atleast all important features in the operation and maintenance of a system's facilities.

Periodic review of maintenance

These reviews should be in the form of a thorough inspection of all facilities. The principal purpose of the reviews is to verify the safety of the structure: to disclose the level of maintenance and conditions that might cause disruption or failure of operation; to note the extent of deterioration as a basis for planning maintenance, repair, or rehabilitation work; and to obtain operating experience data for improvement of future design, construction, maintenance, and operation practices.

The Financial Dilemma

The most important input for any maintenance effort is financial cover/support. The level of O&M fundng depends on the economic conditions prevalent in the country and the attitude of planners in finance towards the need for maintenance of drainage systems and the importance of their land and crop saving functions.

Consequently the funds allocated for operation and maintenance of works on drainage systems are quite meagre and very much below the actual minimum requirements. Appendices I to III and Table-I, depict the funding status of a typical control area designated as Circle-T, and indicate that the O&M funds have been reduced over the years, although the fild requirements have progressively increased on account of general escalation and continued inflationary trends. The outcome is obvious; maintenance deferred, and the systems incapacitated.

Conclusions and Recommendations

1) The maintenance of drainage projects/systems has to be planned carefully, much the same way as the feasibility or construction of a development project.

2) Maintenance programmes and Manuals need to be prepared properly and implemented as far as possible in letter and spirit.

3) The Biological Control methods promise a break through and should be tried on some selected drains.

4) Strict control over natural and industrial wasteways, and pollution of drainage channels is now inescapable to save he health of humans and animals. The "Draft Pollution Control Ordinance" prepared in 1977, must be promulgated and enforced before it is too late.

5) There is a definite need for increasing maintenance grants at least to required minima, if we want to save our projects, environments, and the development money put in them.

6) The need for Research to develope new ideas and methods for maintenance of drains is an established fact and we should take necesary steps in this direction.

Appendix-I

A TYPICAL DRAINAGE CIRCLE

STATEMENT SHOWING AVAILABILITY OF FUNDS AND EXPENDITURE UNDER MAINTENANCE AND REPAIRS DURING 1984-5 TO 1989-90.

Sl. No.	Year	DRAINAGE DIVISION -I		DRAINAGE DIVISION-II		TOTAL	
		Availability of Funds	Expenditure	Availability of Funds	Expenditure	Availability of Funds	Expenditure
1.	1984-85	26,17,000.00	26,26,030.00	15,60,000.00	15,60,224.00	41,77,000.00	41,86,254.00
2.	1985-86	28,67,000.00	28,37,659.00	13,50,000.00	13,31,709.00	42,17,000.00	41,69,368.00
3.	1986-87	13,81,300.00	13,92,407.00	28,22,400.00	28,25,937.00	42,03,700.00	42,18,341.00
4.	1987-88	10,87,200.00	10,92,851.00	25,00,000.00	25,09,890.00	35,87,200.00	36,02,741.00
5.	1988-89	14,07,600.00	14,23,803.00	19,50,000.00	19,53,505.00	33,57,600.00	33,77,308.00
6.	1989-90	5,00,000.00 Upto 1/90	1,17,742.00	7,64,800.00 Upto 1/90	2,27,444.00	12,64,800.00	9,92,244.00

Appendix-II

STATEMENT SHOWING LENGTH OF DRAINS (SYSTEM WISE) IN CANAL MILES IN CIRCLE-T

DIVISION -I

S.No.	NAME OF DRAINAGE SYSTEM	BED WIDTH BELOW 10'	BED WIDTH 10'-15'	BED WIDTH OVER 15'	CATCHMENT AREA IN SQ.MILES	DISCHARGE AT O/FALL IN CUSECS	REMARKS
1	2	3	4	5	6	7	8
1.	Drainage System-A	118.13	27.59	91.07	385.5	771.0 Cs	
2.	Drainage System-B	15.09	-	35.34	406.2	812.0 Cs	
3.	Drainage System-C	25.01	13.00	29.60	222.5	656.0 Cs	
4.	Drainage System-D	28.63	-	28.74	375.0	750.0 Cs	
5.	Drainage System-E	24.73	-	11.10	376.0	752.0 Cs	
6.	Drainage System-F	6.55	-	-	16.0	32.0 Cs	
7.	Drainage System-G	4.20	-	-	8.0	22.0 Cs	
	DIVISION-II						
8.	Drainage System-H	162.85	74.28	113.80	1263.60	521.0 Cs	
9.	Drainage System-J	41.66	-	34.14	352.00	704.0 Cs	
10.	Drainage System-K	16.97	10.91	11.80	52.50	232.0 Cs	
11.	Drainage System-L	39.75	15.60	25.02			
12.	Drainage System-M	25.32	-	35.80	98.00	196.0 Cs	
13.	Drainage System-N	43.01	14.40	18.67	462.00	924.0 Cs	
14.	Individual Drains-P	36.00	-	-	46.00	141 Cs	
	Total;	587.9	115.78	435.08		6513	

TABLE-I

COMPARISON OF YARDSTICK ALLOCATIONS,
& EXPENDITURE FOR DRAINAGE CIRCLE-T

All figures in thousand Rupees.

S.No.	F-Year	Yardstick Allocation	Actual Allocation	Expenditure	Remarks
1	2	3	4	5	6
1.	1984-85	5,040	4,177	4,186	
2.	1985-86	5,390	4,217	4,169	
3.	1986-87	5,770	4,204	4,218	
4.	1987-88	6,170	3,587	3,603	
5.	1988-89	6,610	3,357	3,377	
6.	1989-90 (Half year)	3,540	1,265	992	

NOTE:- The falling trend of allocations in the face of continuous inflation/escalation is conspicuous.

Appendix-III

A TYPICAL DRAINAGE CIRCLE-T

REQUIRED O&M FUNDS ALLOCATION AS PER YARDSTICK (BASE YEAR 1981-82)

1.	587.9 Miles bed width below 10' @ 2000/- per mile	=	1,175,800
2.	155.8 Miles bed width 10-15' @ 3500/-er per mile	=	545,300
3.	435.00 Miles bed width over 15' @ 5500/- per mile	=	2,392,500
	Total for 1981-82	=	4,113,600
	Say	=	4.114 million

Adding escalations @ 7% per annum required O&M

allocation for 1982-83	=	4.40	"
1983-84	=	4.71	"
1984-85	=	5.09	"
1985-86	=	5.39	"
1986-87	=	5.77	"
1987-88	=	6.17	"
1988-89	=	6.61	"
1989-90	=	7.07	"

Note:- Corresponding actual allocation figures have been compared in Table-I

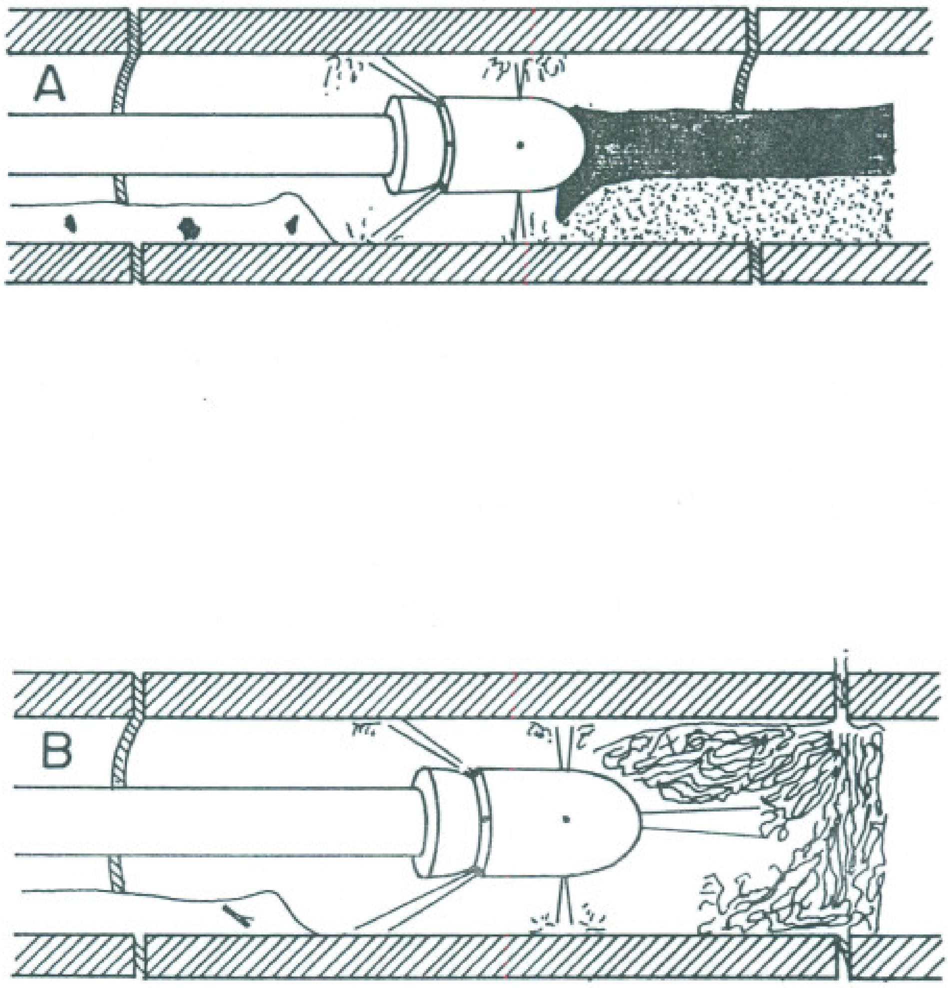

Figure 1 - Use of high-pressure jet nozzles in subsurface drains. A, Scouring and removing silt and mineral deposits; B. removing roots.

Courtesy-U.S.D.A.

BIBLIOGRAPHY

1. Farr, E. and Henderson W.C., 1986. Land Drainage, Longman, London.

2. Framji, K.K., 1984. Second N.D. Gulhati Memorial Lecture for International Cooperation in Irrigation and Drainage. 12th. Congress of ICID, Fort Collins, CD.USA.

3. Grass L.B. and Mackenzie, 1972. Soil Sediment Deposition in Drains, Transactions of the ASAE. 1972.

4. Harrison, D.S. et. al. 1966. Aquatic Weed Control in Ponds, drains, canals and streams. Circular 219 b, University of Florida Agricultural Extension Service, Gainsville.

5. Kanwar, R.S., and S.P. Johnson, etc. al. 1982. Drainage needs and returns in North Central Iowa. Transactions of the ASEA 1982. Paper No. 82-2078.

6. Nolte, B.H., 1979. Tile Drain Life. Transactions of the ASAE, Paper No. 79-2550, St. Joseph, HI. 49085.

7. P.E.C. 1983 Control of Waterlogging and Salinity in Pakistan.

8. Roe and Ayres, 1954. Engineering for Agricultural Drainage. McGraw Hill Company, Inc. New York,.

9. Shafer, F.F; 1940. Causes of Failures in Tile Drains. Agricultural Engineering, Vol. 21, No. 1-17-18, 20.

10. Twogood, D.A., 1985. Drain maintenance in the Imperial Valley, Proceedings of the Specialty Conference by ASCE.

11. U.S.D.A. 1975 - Inspecting and Cleaning Subsurface Drain Systems.

12. ZAIDI. Et. al. 1984, Waterlogging and Salinity in Punjab.

List of Symposia

Volume No.	Year	Subject
1	FEB. 1957	HOUSING PROBLEMS OF WEST PAKISTAN
2	FEB. 1958	FLOOD IN WEST PAKISTAN
3	FEB. 1959	WATERLOGGING AND SALINITY IN WEST PAKISTAN
4	FEB. 1960	ENGINEERING EDUCATION IN PAKISTAN
5	MAR. 1961	PLANNING AND EXECUTION OF ENGINEERING PROJECTS IN PAKISTAN
6	APR. 1962	SEDIMENTATION AS A RESULT OF INDUS BASIN WORKS
7	OCT. 1963	WATERLOGGING AND SALINITY IN WEST PAKISTAN
8	MAR. 1965	CONSULTING AND CONTRACTING PRACTICES IN PAKISTAN
9	OCT. 1966	ENGINEERING RESEARCH IN DEVELOPING ECONOMY OF PAKISTAN
10	1068	BRIDGES
11	1969	WATER RESOURCES DEVELOPMENT
12	1969	PROBLEMS OF ENGINEERING PROFESSION IN PAKISTAN
13	1972	PLANNING FOR NATIONAL OBJECTIVES
14	1974	UTILIZATION OF NATURAL RESOURCES IN PAKISTAN FOR SELF RELIANCE
15	1975	TARBELA DAM-PROBLEMS & SOLUTIONS
16	1978	LOW-COST STRUCTURES
17	1982	ENGINEERS ROLE IN PLANNING, EXECUTION AND MANAGEMENT OF PROJECTS
18	1985	RURAL DEVELOPMENT
19	1986	ENERGY CRISIS
20	1987	QUALITY CONTROL AND MATERIALS
21	JAN. 1989	HYDRO ELECTRIC POWER IN PAKISTAN
22	MAY 1990	OPERATION AND MAINTENANCE OF COMPLETED PROJECTS