An assessment of the crop water demand and irrigation water supply at Pabbi minor of Warsak gravity canal

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Abstract: The research study was conducted on irrigation water supply and demand at Pabbi minor of Warsak gravity canal from June to August 1998. Objectives of the research were to assess the actual supply of irrigation water, irrigation water demand of major crops, and comparison between water supply and demand for all the outlets of Pabbi minor. Actual irrigation supply was determined by cutthroam flumes. Cropping pattern was determined by interviewing the farmers by making use of proformas developed for that purpose.

Key words: Cropping pattern, evapotranspiration, sanctioned discharge, fallow, water demand, water supply

1. Introduction

Pakistan's agriculture is predominantly irrigated and is based on one of the oldest and largest contiguous gravity flow irrigation system in the world. The Indus Basin irrigation system encompasses the Indus river and its tributaries, three major storage reservoirs, 19 barrages/headworks, 12 link canals and 43 canal commands. The total length of the canal system is 40,000 miles with 80,000 watercourses and field ditches running another 1.0 million miles. (Ali, 1993). In canal irrigation system, farmers are not independent in their choice of growing crops because they have to adjust their cropping patterns according to the available water supply. For proper development of agriculture, it is very important to conduct studies at various places to determine the difference water supplied and water requirement of the crops in that area to assess whether irrigation water is according to the demands of the crops or not. That is why a shift from the traditional supply oriented system of irrigation operations to one that is based on demand, or to one that corresponds to crop-water requirements, is among the most challenging issues confronting Pakistan's irrigation system. In order to put more and more area under irrigation, water has to be conserved and present available water should be efficiently used. It is desirable to reduce water losses in the field by finding out the actual crop water requirement, and compare it with the water supplied to ensure an equitable supple of water to all the farmers in an irrigation unit throughout the year. This study was undertaken to compare the available water supply with the crop water requirements under the traditional gravity irrigation system.

Main objectives of this study were:

1. To determine cropping pattern at the outlets of Pabbi minor
2. To determine crop water demands at the outlets
3. To measure the irrigation water supply to the outlets
4. To compare available irrigation water supplies to the crops water demand in the area

2. Materials and Methods

2.1 Site Description

This research work was conducted at the Pabbi minor of Warsak Gravity Canal (WGC). This canal off takes at the exit of 5.6 kilometers (km) tunnel through Mullagori hills on right bank of river Kabul and upstream of Warsak dam. The total length of WGC is 72.8 km and has full supply discharge (FSD) of 311 cusecs. The Culturable Command Area (CCA) of this canal is 58,681 acres, and has eleven minors, out of which, Pabbi minor is situated at the tail. Pabbi minor is 8000 ft. in length with a design discharge of 6.5 cusecs, while the sanctioned discharge is 3.53 cusecs. The gross command area (GCA) of this minor is 1010 acres, whereas CCA is 909 acres. Pabbi minor has six outlets; 600/R, 1308/R, 3900/R, 3900/L, Tail/R and Tail/L, having sanctioned discharges of 0.19 cusecs, 0.19 cusecs, 0.94 cusecs, 0.45 cusecs, 0.81 cusecs and 0.83 cusecs respectively. (Iqbal, 1995)

2.2 Cropping Pattern

Cropping pattern at the outlets was determined by means of proformas which consisted of following questions: farmer's name, total area owned, irrigated area, fallow land, crops grown, date of planting and harvesting, area under specific crop and tenancy status of the farmer etc.

2.3 Crop Water Requirements

For measuring crop water requirements, the following steps were taken:

2.3.1 Reference Crop Evapotranspiration (ETo)

Reference crop evapotranspiration was determined by using the computer software "CROPWAT" (5.7) developed by Land and Water Development Division of FAO. The software utilizes Penman-Montieth method for determination of ETo[57].

2.3.2 Crop Coefficient (Kc)

The effect of crop characteristics on crop water requirements is given by crop coefficients. It represents relationship between reference evapotranspiration (ETo) and crop evapotranspiration (Etc). Kc values for different crops used as reported in the Water management manual, FAO 24 for the research period.

Weighted Kc (<u>Kc</u>).

$$Kc = \frac{Kc_1(A_1) + Kc_2(A_2) + \ldots + Kc_n(A_n)}{A_1 + A_2 + \ldots + A_n}$$

[57] ETo= C[W.Rn+(l-w)fu][ea-ed] where, C is adjustment factor, W is weighted factor related to temperature
Rn is solar Radiation, f(u) is wind related function
(ea-ed) is difference between saturated and actual vapor pressure

2.3.3 Crop Evapotranspiration (Etc)

Crop evapotranspiration (Etc) were determined by multiplying the Kc value for each month with the ETo value for the respective month.

2.3.4 Effective Rainfall (P_{eff})

CROPWAT computed the effective rainfall by using rainfall data from Agricultural Research Institute, Tarnab. Fixed percentage (80%) formula was used for computation of effective rainfall.

P_{eff}= 80% P_e Rainfall (mm/month), where P_e is total monthly rainfall (mm/month)

2.3.5 Net Irrigation Requirements (In)

The monthly net irrigation requirement in mm/day was calculated as:

In (mm/day)= Etc-P_{eff}

2.3.6 Gross Irrigation Requirements (Ig)

Gross irrigation requirements in mm/day were obtained by the use of an assumed efficiency value of 65% for the whole system.

2.4 Flow Measurements at the outlets

Discharge measurements at the outlets were accomplished using "Cutthroat flumes" which are used to measure flow in watercourses.

3. Results and Discussions

Results of the study regarding comparison of water supply with crop water demand at all the six outlets are given in the preceding sections:

3.1 Cropping Pattern

Due to the non-availability of adequate irrigation water at the outlets, farmers had left major portion of the area as fallow. Major crops grown were Maize, Sugarcane, Orchards, Tomatoes and Cucumbers. At outlet no. 600/R, Sugarcane covered major parts, 3.68 hectares (ha) or 42.1% of the cultivated area. At outlet no. 1300/R, Maize was the dominant crop covering 10 ha (35%) area. At outlet no. 3900/R, sugarcane remained dominant covering 26.28 ha (26%) of cultivated area. At outlet no. 3900/L, Maize was dominant covering 14.32 ha (29%) of the cultivated area. At outlet Tail/R, orchards were dominant covering 13.9 ha (16%) of the cultivated area. At outlet Tail/L, Maize remained dominant crop covering 18.48 ha (20%) of the cultivated area. Hence, throughout the season, Maize was the dominant crop covering major proportion of the cultivated area.

3.2 Crop Water Requirements

Crop Water Requirements were calculated by taking into account the reference crop evapotranspiration, effective rainfall, crop coefficient values and crop evapotranspiration values.

3.2.1 Reference Crop Evapotranspiration (ETo) and Effective Rainfall (Peff.)

ETo was calculated for the whole year (1998) from climatic data obtained from Agriculture Research Institute, Tarnab. CROPWAT software calculated ETo values for the whole year, which showed maximum ETo value of 6.1 mm/day in June and minimum value of 1.4 mm/day in December. Values of Peff. were also calculated from the climatic data. Maximum value of 93.9 mm/day was observed in February where minimum value of 5.16 mm/day observed in November. Values of ETo and Peff. are given in the following table:

Table 1: Reference Crop Evapotranspiration (ETo) and Effective Rainfall (Peff.)

Months	ETo (mm/day)	Peff. (mm/month)	Peff. (mm/day)
January	1.7	31.7	1.05
February	2.1	93.9	3.13
March	3.1	49.1	1.63
April	4.3	76.9	2.56
May	5.6	22.5	0.75
June	6.1	10.6	0.35
July	5.6	64.5	2.15
August	5.2	36.6	1.22
September	4.6	40.0	1.33
October	3.4	14.4	0.48
November	1.9	5.6	0.18
December	1.4	21.9	0.73

Source: Agriculture Research Institute Tarnab (1998)

3.2.2 Crop Coefficient (Kc)

Kc values for different crops are given the preceding table. It is clear from the table that the Kc values of perennial crops, sugarcane, peaches and plums remained the same throughout the research period, because they were in development stage. In June, maize was in initial stage, and in July and August it entered the development stage, so the Kc values increased. Tomato, in July and August was in late season stage, and so Kc decreased.

Table 2: Crop Coefficient (Kc) values

Crop	June	July	August
Maize	0.6	0.95	1.02
Sugarcane	0.85	0.85	0.85
Tomato	1.15	0.87	0.87
Cucumber	0.95	0.97	1
Peaches	1.15	1.15	1.15
Plums	1.15	1.15	1.15

Source: Pakistan Agriculture Research Council (1982)

3.2.3 Wighted Kc (Kc)

The value of weighted Kc were calculated and given in the following table:

Table 3: Wighted Kc (Kc) values

Outlet No.	June	July	August
600/R	0.73	0.89	0.92
1308/R	0.82	0.95	0.93
3900/R	0.81	0.92	0.93
3900/L	0.76	0.92	0.93
Tail/R	0.88	0.99	0.96
Tail/L	0.9	0.94	0.75

Source: Field survey (1998)

3.2.4 Crop Evapotranspiration (Etc)

Etc values or individual months at the outlets are given in the following table:

Table 4: Crop Evapotranspiration (Etc) values

Outlet No.	June	July	August
600/R	4.45	4.98	4.78
1308/R	5	5.32	4.83
3900/R	4.9	5.1	4.8
3900/L	4.6	5.1	4.78
Tail/R	5.36	5.5	5
Tail/L	5.49	5.26	3.9

Source: Field Survey (1998)

3.2.5 Irrigation Requirements

Preceding table shows the monthly net irrigation requirements (In) and gross irrigation requirements (Ig) in mm/day. It is evident from the table that crops demand at outlet no. 600/R was minimum, because of having a small CCA; supply at 600/R thus exceeded crops demand. Whereas cops demand at Tail/R was maximum and exceeded the available water supply; major proportion of the area was left fallow.

Table 5: Irrigation Requirements at the outlets

Outlet No.	June		July		August	
	In	Ig	In	Ig	In	Ig
600/R	4.1	5.8	2.83	4.04	3.56	5.08
1308/R	4.65	6.5	3.17	4.5	3.61	5.1
3900/R	4.55	6.5	2.95	4.21	3.58	5.1
3900/L	4.25	6.07	2.95	4.21	3.56	5
Tail/R	5.01	7.1	3.35	4.7	3.78	5.4
Tail/L	5.14	7.3	3.11	4.4	2.68	3.8

Source: Field Survey (1998)

3.3 Actual Water Supply

Water supply data is shown on decade basis in the preceding table for the outlet. It can be noted from the data that water supply to outlet no. 600/R was maximum and was minimum to outlet Tail/L. High seasonal evaporation losses and seepage losses as well as illegal water withdrawal could be some reasons attributed to the scenario.

Table 6: Actual Water Supply at the outlets

	600/R	1308/R	3900/R	3900/L	Tail/R	Tail/L
June 1	6	3.8	2.9	5.3	1.6	1.3
June 2	6.7	4.3	2.97	5.6	1.9	1.5
June 3	6.1	3.7	2.8	5.4	1.1	1
July 1	6.4	4.2	2.8	4.9	0.9	1
July 2	6.2	4	2.7	4.8	1.4	1.2
July 3	6	4	2.7	4.9	1.1	0.9
August 1	6.3	4	2.9	4.8	1.2	1
August 2	6.8	4.4	3	5.6	1.3	1.1
August 3	6.7	4.4	3	5.1	1.2	1

Source: Field Survey (1998)

3.4 Sanctioned Water Supply

The sanctioned water supply or allocated water supply, as allowed by Provincial Irrigation Department (P.I.D) was taken into account to make comparisons.

3.5 Comparisons

Comparisons between total actual supply and water demand are discussed in the preceding sections and presented graphically. In the figures, Qa represent actual discharge, Qd is the water demand and Qs is the government sanctioned supply discharge.

3.5.1 Outlet No. 600/R

In June, water demand was 5.80 mm/day. Average supply in first decade of June (June-I) was 6 mm/day. Average supply in second decade of June (June-II) was 6.7 mm/day. Average supply in third decade of June (June-III) was 6.19 mm/day. Thus in June, actual supply was 8% more than the demand. In July, average water demand was 4.04 mm/day. Average supply in July-I was 6.4 mm/day. Average supply in July-II was 6.8 mm/day and average supply in July-III was 6 mm/day. Throughout July, average supply was 6.25 mm/day and exceeded the crops water demand by 35%. In August, water demand throughout the month was 5.08 mm/day. Average supply August-I was 6.3 mm/day. Average supply in August-II was 6.8 mm/day and in August-III was 6.7 mm/day. Throughout August, average supply was 6.8 mm/day and was 25% more than the demand.

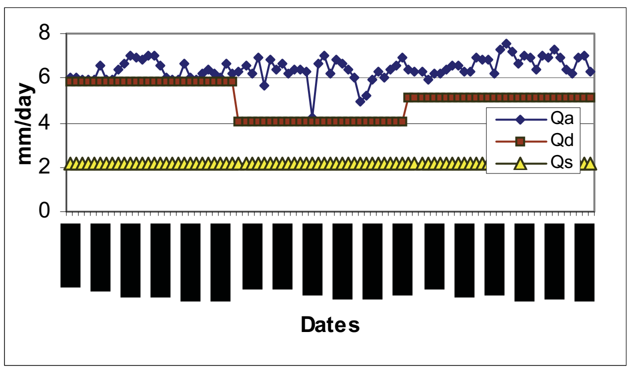

Figure no. 1: Demand and Supply at outlet no. 600/R

3.5.2 Outlet No. 1308/R

In June, irrigation water demand was 6.6 mm/day. Average supply in June-I was 3.8 mm/day. Average supply in June-II was 4.31 mm/day and in June-III was 3.7 mm/day. Throughout June, average supply was 3.97 mm/day. Thus in June, irrigation water demand was 39.8% more than the actual supply. In July, irrigation water demand was 4.5 mm/day throughout the month. Average supply in July-I was 4.2 mm/day, average supply in July-II was 4 mm/day and in July-III was 4 mm/day. Throughout July, average supply was 4 mm/day. Thus in July, irrigation water demand was 11.1% more than actual water supplied. In August, irrigation water demand was 5.1 mm/day throughout the month. Average supply in August-I was 4 mm/day, in August-Ii was 4.4 mm/day and in August-III was 4.4 mm/day. Throughout July, average water supplied was 4.27 mm/day. Thus in August, irrigation water demand was 16% more than actual supply.

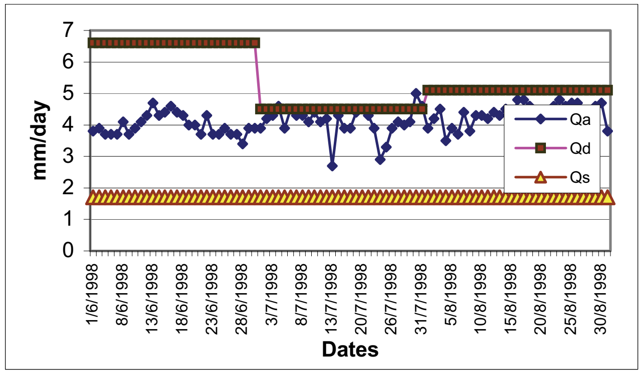

Figure no. 2: Demand and Supply at outlet no. 1308/R

3.5.3 Outlet No. 3900/R

In June, irrigation water demand was 6.5 mm/day throughout the month. Average supply in June-I was 2.9 mm/day, average supply in June-II was 2.9 mm/day, and average supply in June-III was 2.8 mm/day. Throughout June, average water supplied was 2.9 mm/day. Thus in June, irrigation water demand exceeded the water supplied by 55%. In July, irrigation water demand was 4.2 mm/day throughout the month. Average supply in July-I was 2.8 mm/day, in July-II was 2.7 mm/day and in July-III was 2.7 mm/day. Throughout July, average water supply was 2.7 mm/day. Thus in July, irrigation water demand was 38% more than actual supply. In August, irrigation water demand was 5.1 mm/day throughout the month. Average water supply in August-I was 2.9 mm/day; average water supply in August-II was3 mm/day and in August-III was 3 mm/day. Throughout August, average water supply was 2.98 mm/day. Thus in August, irrigation water demand was 41.5% more than actual supply.

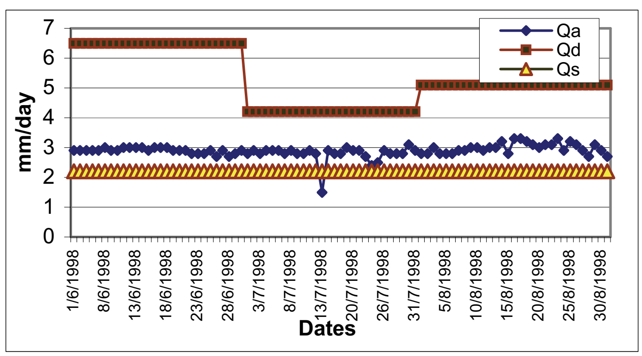

Figure no. 3: Demand and Supply at outlet no. 3900/R

3.5.4 Outlet No. 3900/L

In June, irrigation water demand was 6.07 mm/day throughout the month. Average supply in June-I was 5.3 mm/day, average supply in June-II was 5.6 mm/day and in June-III was 4.4 mm/day. Throughout June, average water supply was 5.14 mm/day. Therefore in June, water demand was 15% more than actual supply. In July, irrigation water demand was 4.21 mm/day throughout the month. Average supply in July-I was 4.9 mm/day, average supply in July-II was 4.8 mm/day, and average supply in July-III was 4.9 mm/day. Throughout July, average water supply was 4.9 mm/day.

Thus in July, water supply was 14% more than water demand. In August, irrigation water demand was 5.0 mm/day throughout the month. Average supply in August-I was 4.8 mm/day, in August-II was 5.6 mm/day, and in August-III was 5.1 m/day. Throughout August, average water supplied was 5.2 mm/day. Thus in August, water supply was 4% more than water demand.

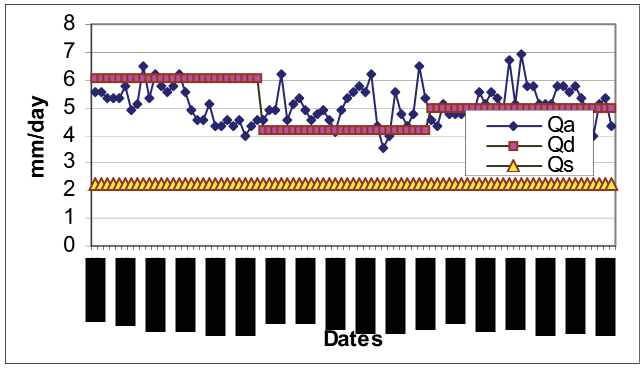

Figure no. 4: Demand and Supply at outlet no. 3900/L

3.5.5 Outlet Tail/R

In June, irrigation water demand was 7.10 mm/day throughout the month. Average water supply in June-I was 1.6 mm/day, average supply in June-II was 1.9 mm/day and average supply in June-III was 1.1 mm/day. Throughout June, average water supply was 1.59 mm/day. Thus in June, water demand was 77.6% more than water supply. In July, irrigation water demand was 4.70 mm/day throughout the month. Average supply in July-I was 0.9 mm/day, average supply in July-II was 1.4 mm/day, and in July-III was 1.1 mm/day. Throughout July, average supply was 1.3 mm/day. Thus in July, water demand was 72% more than water supply. In August, water demand was 5.40 mm/day throughout the month. Average supply in August-I was 1.2 mm/day, in August-II was 1.3 mm/day and in August-III was 1.2 mm/day. Throughout August, average supply was 1.29 mm/day. Thus in August, water demand was 76% more than actual water supply.

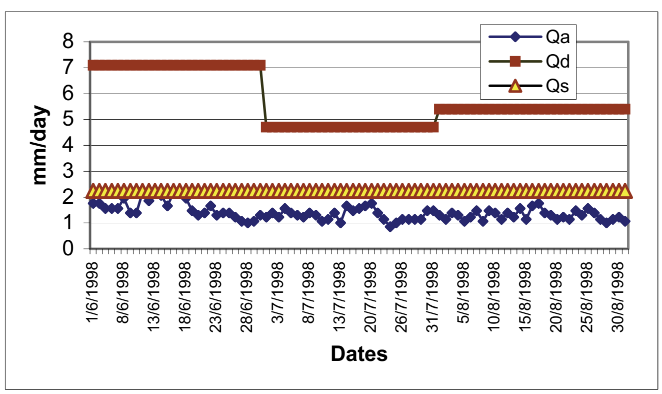

Figure no. 5: Demand and Supply at outlet Tail/R

3.5.6 Outlet Tail/L

In June, irrigation water demand was 7.3 mm/day throughout the month. Average supply in June-I was 1.3 mm/day. In June-II, average supply was 1.5 mm/day, and in June-III, average supply was 1 mm/day. Throughout June, average supply was 1.35 mm/day. Thus in June, water demand was 81.55 more than the water supplied. In July, irrigation water demand was 4.4 mm/day. In July-I, average water supply was 1 mm/day. In July-II, average water supply was 1.2 mm/day and in July-III, average water supply was 0.9 mm/day. Throughout July, average water supply was 1.09 mm/day. Thus in July, water demand was 75.2% more than water supplied. In August, water demand was 3.8 mm/day throughout the month. Average water supply in August-I was 1 mm/day, in August-II was 1.1 mm/day and in August-III was 1 mm/day. Throughout August, average was supply was 1.08 mm/day. Thus in August, water demand was 71.5% more than water supply.

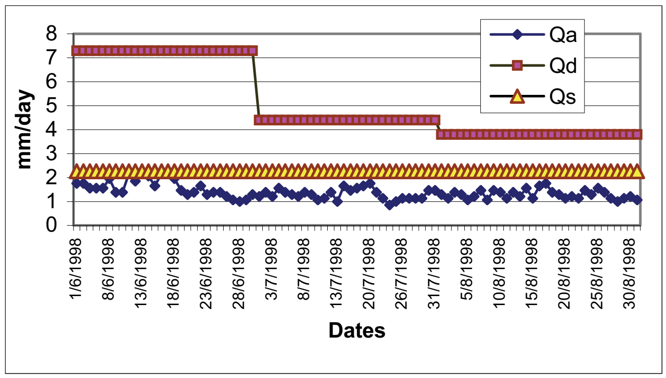

Figure no. 6: Demand and Supply at outlet Tail/L

3.6 Overall Comparison

Throughout the research period, irrigation water demand was 46% more than water supply in June, 22% more than water supply in July, and 26% more than actual water supply in August. High temperature and less rainfall in the month of June can here be attributed to an elevated water demand in this month. Due to this mismatch between water demand and supply, farmers had left major proportions of the culturable area as fallow. The fact of outlet no. 600\R being located along the head of Pabbi minor is attributed to lesser water demand here, whereas outlet no. 3900/L had a small CCA and supply here surpassed the crops water demand. As with other outlets, high water demanding crops (sugarcane, maize, vegetables etc) and fairly high culturable areas restricted adequate water supply to fulfill the crops water demands. In June, July and August, actual supply was more than the government sanctioned supply by 40%, 36% and 41% respectively.

Results achieved from this research study differ from the results achieved during similar research study at Turlandi minor by Paracha (1998). His results showed that at Turlandi minor of Lower Swat Canal, water supply to the area was in excess of the irrigation water demand, due to very low evapotranspiration that occurred during the research period. Especially during October, supplies were very high as compared to demand due to maximum rainfall (104.2 mm). High water allowance of the minor was another reason for excess water supply. Also Iqbal (1995) obtained results, which showed more supply as compared to crops demand in the head of minor, whereas in middle, supply was less than demand due to greater CCA, and in tail of minor, supply was in excess as a consequence of a small CCA.

4. Conclusions and Recommendations

It was concluded from this study that due to non-availability of adequate amount of water, major proportion of the culturable command areas at the outlets were left as fallow. Maize was the most dominant crop and was being utilized as a staple food. Water supply to outlet no. 600/R and 3900/L was more than the demand by 23.1% and 7.2% respectively. At all the other outlets, crops demand exceeded the available water supply. At outlet no.1308/R, it exceeded by 24.4%, at outlet no. 3900/R by 45.7%, at outlet Tail/R by 75.7% and at outlet Tail/L by 77.3%. Overall, irrigation water demand exceeded the actual supply in June, July and August by 46%, 22% and 26% respectively.

It is recommended on the basis of this study to perform similar kind of research studies for Rabi (winter) season to compare water required and supply. Also, cropping pattern, which was assessed by proforma method, may also be done by other methods, e.g. stepping method, to compare results of both the methods. It is also a dire need and a vital recommendation to conduct studies of similar capacity for assessing crops water demands at the command areas under the irrigation system hierarchy, which could help scientists in achieving new modes of demand-based irrigation systems.

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