EVALUATION OF GROUNDWATER OF RECHARGE FROM LAKES

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BACKGROUND

Hyderabad is the fastest growing city in India. During the last 40 years, the population of Hyderabad has grown rapidly from 1.4 million (1961) to almost 5 million at present. Simultaneously, population density increased by 50% and land use changed dramatically in large parts of the city. Historically, urban lakes have been used as a buffer for runoff and as storage of rainwater for later use. In the past, Hyderabad counted more than 500 artificial and natural lakes. Artificial lakes were formed by constructing bunds across seasonal streams. Lakes were interconnected so that during high intensity rainfall, higher lakes overflowed in lakes lower down the watershed. Stored rainwater was used for domestic and irrigation purposes. As a result of the rapid and uncontrolled urban growth and the consequent changes of land use, the functioning of this network of urban lakes is deteriorating rapidly: lakes have been encroached upon and polluted, and linkages have been blocked. The number of water bodies, once 530 is down to 150 at present.

The Integrated Lake Management (ILTM) component of GHEP has initiated restoration of lake bodies, treat the polluted lakes and protect treated lakes from future pollution and encroachment.

Ground water recharge facilitated by the lakes has always been taken for granted, however there has been no quantification of the same. As part of ILTM detailed hydro geological studies is being carried out to assess the recharging capacities of the lakes, map their area of influence and study the impact of lake recharge on quality of water in the wells. The study involves monitoring representative groundwater structures (open hand dug wells and drilled bore wells) in 109 representative wells around 10 lakes . The monitored lakes include

Lake Name	Location	No of monitoring wells
Safilguda	Malkajigiri	9
Rayasamudram	Ramchandrapuram (GP)	12
Nalla cheruvu	Uppal	17
Pedda cheruvu	Kapra	14
Patel cheruvu	Kapra	12
Hasmathpet	Kukatpally/Cantonment/Alwal	15
Mukkidi cheruvu	Kapra	8
Banda cheruvu	Malkajgiri	8
Nalla cheruvu	Serlingampally	7
Sudulavani	Serlingampally	7

The objective of the monitoring is to:

- Understand the relationship between the lakes and groundwater system.
- Correlate the groundwater monitoring data with the lake water balance computations.
- Delineate the aerial extent of influence of the lake on the groundwater system.
- Appreciate the impact of the pollution in the lake on the groundwater quality.
- Extrapolate the results from the monitoring to other areas.

The 109 monitoring wells include 64 Open Hand Dug Wells and 45 Bore Wells. The groundwater levels is being monitored regularly on a monthly basis and water quality measurements are carried out quarterly.

METHODOLOGY OF MONITORING

As part of the methodology number of groundwater structures have been selected as monitoring wells. The selected monitoring wells are those wells which show sympathetic response to lake water level fluctuations and water quality changes. The selection of the monitoring wells is in such a way as to get a good areal coverage around the lake, cover different habitations and monitor the different aquifers tapped by the wells. As part of the measurement the following parameters are monitored.

Field measurements carried out
Date of Measurement
Time of measurement
Height of Measuring Point (m)
Elevation of Measuring Point (m)
Water Level Below Measuring Point BMP (m)
Elevation of Ground Water Level (m)
Water quality (11 parameters)

The following water quality parameters are analyzed for groundwater wells

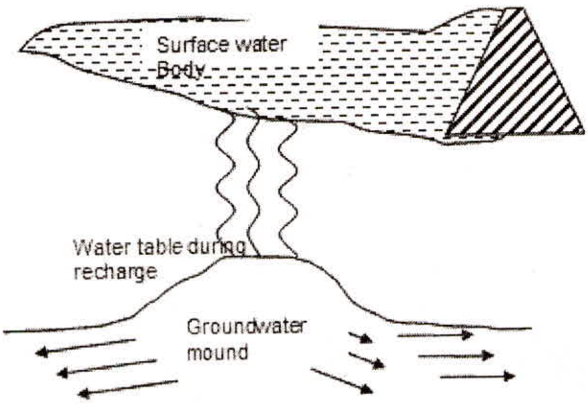
pH,
Electrical Conductivity,
TDS,
Temperature,
Alkalinity,
Total Hardness,
Calcium,
Magnesium,
Chlorides,
Phosphates
Nitrates

All the data collected from the monitoring is being systematically organized in a dedicated data base referred to as Hyderabad Environment Lake Management (HELM) Software. The data has been systematically analysed for generating hydrographs and water level contour maps. The groundwater elevation maps are interpreted to understand the recharge, areal extent of recharge and estimate the quantity of recharge. To help quantify the extent of recharge infiltration studies using double ring infiltrometer are being carried out in the lakes where lake beds are exposed, and also in the water body itself.

GROUNDWATER RECHARGE PROCESS

Aquifer recharge from the lakes is facilitated through the process of Infiltration. Typically all the lakes provide infiltration as seepage from the lakebed but not all the infiltrated water reaches the water table to recharge the aquifer. The infiltration from the lakes is controlled by lake water column, lake geometry, lakebed profile, quality of the stored water, nature of the aquifer in the area and the groundwater development status in its neighbourhood.

Infiltration rates are likely to vary from lake to lake and are a function of the hydraulic conductivity of the exposed lakebed, presence of clogging layers if any and the depth of the water table. The water initially seeps through the lakebed, a portion of it flows laterally (interflow), and some continues to percolate deeper. This infiltrated water eventually reaches the saturated zone and recharge groundwater supply.



Continued arrival of infiltrated water from the lakebed to the saturated zone results in the formation of a groundwater mound. In areas where the aquifer is highly transmissive it permits the recharge water to flow laterally away from the recharge area thus preventing the formation of high groundwater mounds. Development of mound generally limits the infiltration rate. The groundwater mound will be formed only till the infiltration lasts afterwards it dissipates.

Rise and drop in lake water level also result in corresponding rise/drop in pressure head. Additionally the pumping of groundwater from the wells and bore wells create a change in hydraulic head.

TYPICAL RECHARGE PROCESS FROM LAKES

Groundwater impact from safilguda lake a typical lake is discussed. 9 observation wells around safilguda Lake have been regularly monitored. Groundwater levels and lake water levels are connected to a common datum. The lake water level elevation is regularly monitored daily manually. Eight months monitoring data between January– August 2005 is used in the analysis. (see Table at the end)

GROUNDWATER ELEVATION CONTOURS

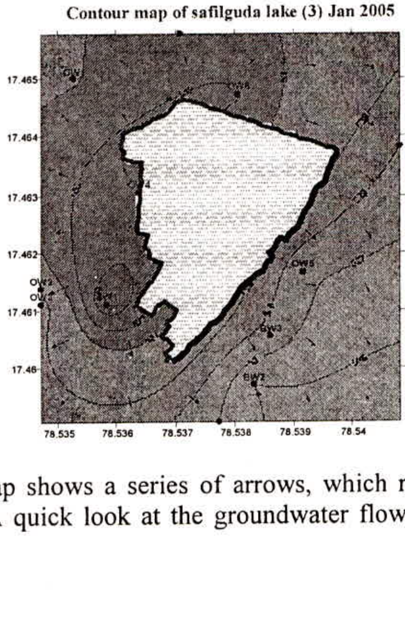
A typical hydrogeologic assumption has been used in developing the estimated groundwater elevation contours (levels and quality). Groundwater surface is assumed to mimic the surface topography, in the absence of information to the contrary. Based on this assumption groundwater elevation contours are drawn after reducing the surface elevation values obtained through reduced level surveys. Groundwater elevation contours are generated for individual wells on a monthly basis to estimated lines of groundwater flow and estimation of groundwater gradients.

Based on the analysis of the monitoring of groundwater level and groundwater quality data it is seen that the lakes provide source for groundwater recharge both to dug wells and bore wells. The response of groundwater table to recharge from the lake is significant in wells closer to the lake while it decreases with distance from the lake and beyond a certain distance no influence of lake recharge is seen.

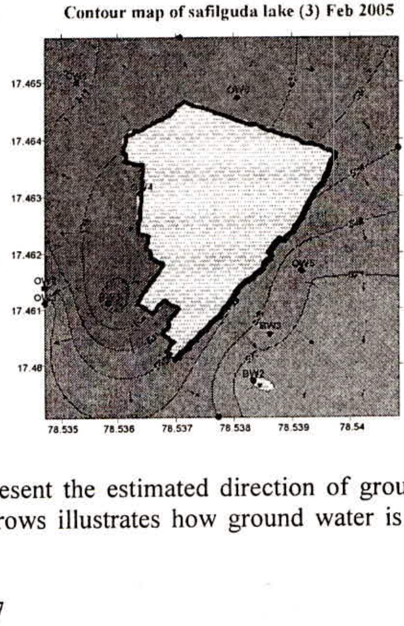
The recharge zones are not uniformly spread around the lakes. Preferred areas for recharge is also seen in few lakes. Large variations in recharge rate and extent of recharge is seen for different periods . Lake induced groundwater recharge is discussed for one lake.

Monthly water level elevation contour maps have been generated for understanding the impact of groundwater replenishment on surrounding wells around the lakes.

Contour map of safilguda lake (3) Jan 2005



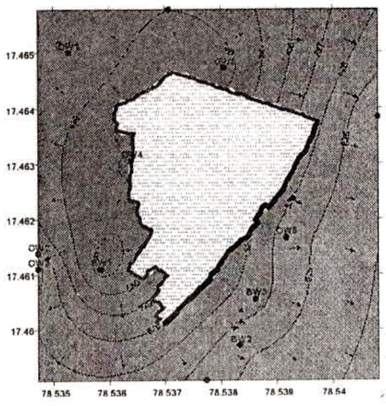
Contour map of safilguda lake (3) Feb 2005



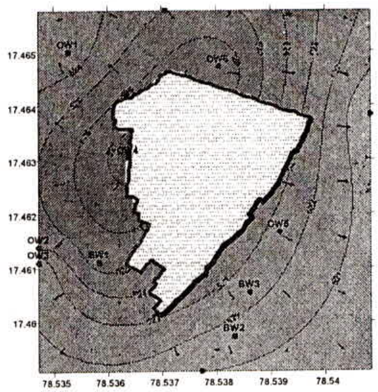
The map shows a series of arrows, which represent the estimated direction of groundwater flow. A quick look at the groundwater flow arrows illustrates how ground water is moving around the lakes (generally in a radial pattern) The groundwater elevation contours for January 2005 shows the formation of ground water mound like feature localized in the North West part of the lake, forming part of Balaram Nagar. The elevation of the mound is 533.5m, which is higher than the lake bed level elevation of 531.70. The mound acts as the focal point from where the recharge dispersion takes place to various areas around Balramnagar and also into the lake. Thus in the month of January the eastern part of the lake facilitates limited groundwater recharge while in the western part and southwestern part groundwater inflow into the lake is seen. The regional recharge zone is located 150m to the west of the lake. The lake facilitates recharge to the south east part extending to 150m in Sharadha Nagar.

In February there is general decline in the ground water elevation by about 0.5m. There is a visible groundwater mound in the west and North West while there is a steep decline in elevation in the south east. The highest elevation on the mound corresponds to 531m, which is a near 2 m decline from January. As determined from the water-level elevation contour map, the hydraulic gradient (slope of the water table) shows slope of 0.01-0.0125m in north and west of the lake while the gradient is of the order of 0.02 – 0.025m in west and south of the lake. Higher gradient are normally associated with recharge areas showing that the southern portion is a major recipient of lake recharge in the month of February.

Contour map of safilguda lake (3) March 2005



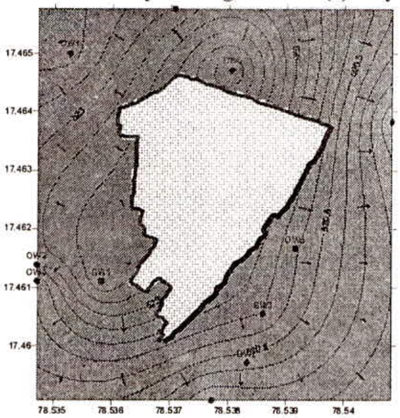
Contour map of safilguda lake (3) April 2005



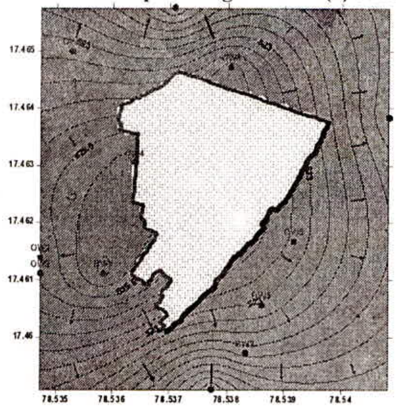
In month of March the ground water mound shows larger extension in the SW part of the lake extending to 150 m into Sri Krishna Nagar. The groundwater gradient extends to the east in the downstream of the lake as far as 180m. The ground water gradient shows 0.02 m in south and southwest, while it is 0.01m west of the lake. Aggravated

In April a sudden drop in the groundwater elevations is witnessed coinciding with steep decline in lake water levels. The drop in groundwater elevation between March and April is of the order of 4-5m drop. A well defined ground water mound reappears localized to the periphery of the lake in the NW part clearly indicating lake induced groundwater recharge all around the lake. The ground water mound enabled recharge is distributed across all directions 150 m in the northwest and 100 m in the southwest of the lake. The elevation of ground water mound is 527 m which is 4 m below the lake bed. The ground water gradient shows 0.02 m in East and 0.025 m. the hydraulic gradient shows that the lake induced recharge is spread all around the lake.

Contour map of safilguda Lake (3) May 2005

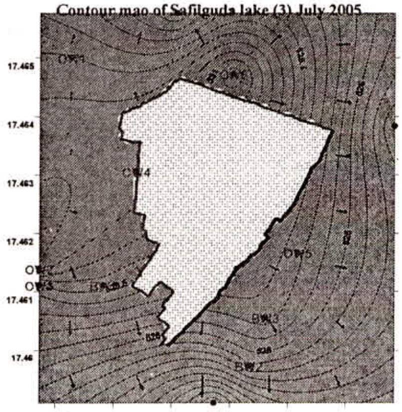


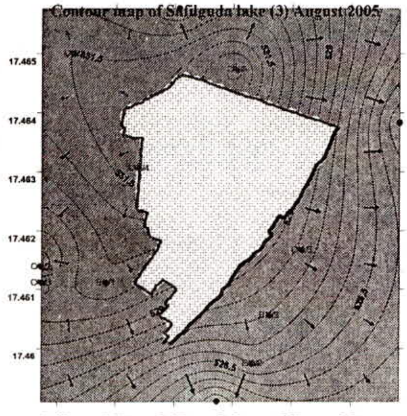
Contour map of safilguda Lake (3) June 2005



In month of May the ground water mound appears very clearly defined in the northern part of the lake around srikrishna Nagar colony. The lake water level is vastly reduced and is almost close to the bed level. The reduced lake water level and increased groundwater abstraction appears to be very well linked. The ground water gradient is 0.02 m in west and 0.015 m in east. The drop in ground water elevation between January and May is close to 8m.

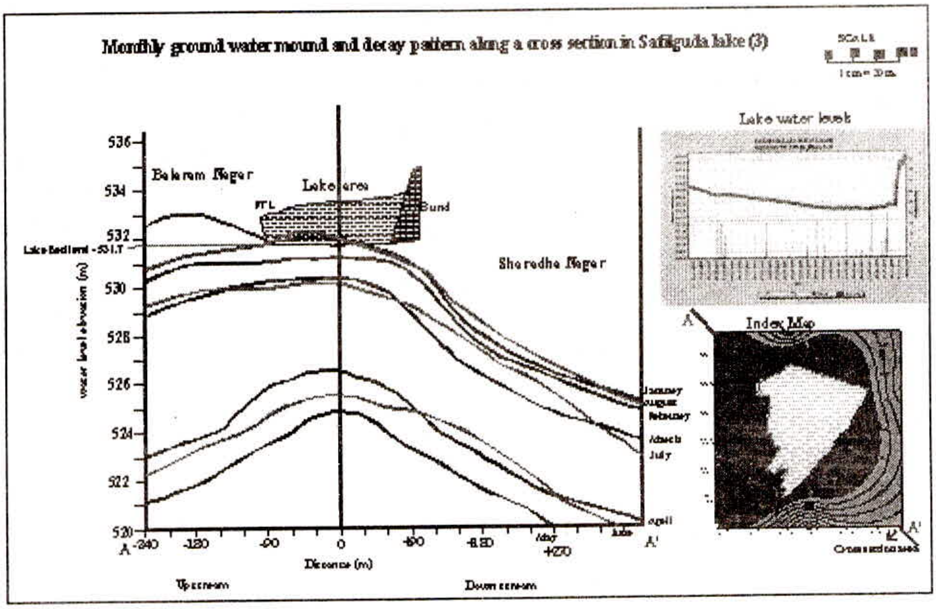
In June to August the impact of rainfall is seen and inflows into the lake creates a rising trend in groundwater elevations and the groundwater mound acquires a larger area. Ground water elevations levels are suddenly rising in all the observation wells. The ground water mound location is also seen to be shifting.





STUDY OF AREAL INFLUENCE OF LAKE RECHARGE

In order to understand the areal extent of recharge water level elevation along a vertical cross section cutting through the centre of the lake and extending from the lake downstream to upstream over 1000 m has been studied. The elevation values provides a good understanding of the recharge impact of the lake on the groundwater system in the lake neighbourhood.



The cross section of water level elevations for the different months shows varying behaviour, however there is consistency in the pattern with the appearance of a mound like feature in the centre and sloping on either sides. The appearance of ground water mound represents the most influential zones of recharge in the lake neighbourhood with raised groundwater levels and declining gradually as one moves away from the lake, finally merging with the regional water level beyond which the influence of lake recharge ceases to extend.

In the month of January and August the maximum elevation groundwater mound is close or above the lake bed level which suggests that groundwater discharges into the lake or there is no significant recharge facilitated from the lake and both the lake water body and ground water system are in equilibrium. In this situation the tank itself is receiving the recharge from regional groundwater system as effluent inflows.

The recharge from the lake begins from February and it continues to extend the areal influence until the local groundwater elevation reaches the deepest levels in May. The extent of recharge influence from the lake is localized and is 240m to the southeast and 200m in the NW. The impact of lake recharge is represented by significant decline in lake water storage which almost reaches the lake bed level in the month of May 2005, when the groundwater level is the deepest.

Steady increase in groundwater elevation begins after the impact of the first monsoon and the water level keeps rising steadily until it comes close to the ground in August.

Thus study of the groundwater mound and decay along a section for number of months shows that influence of recharge varies from month to month depending upon the ground water abstraction represented by groundwater elevation around the lake.

INFILTRATION TEST

In order to assess the rate of recharge Infiltration test was carried out in the water body of the lake using cylinder infiltrometer and measuring the dispersion using Digital Water Level Recorder (DWLR). The purpose of carrying out these tests is to observe the infiltration under saturated and unsaturated condition. The infiltration test was conducted in the dry lake bed as well as within the water body. Infiltration is the process by which water seeps from the lake bed surface into the subsurface. The unsaturated zone consists of soil, air, and water. The pore space within the soil medium is filled with varying amounts of air and water. The dry bed infiltration rate shows several order higher values than in the water body, due to free surface within the pore space. The pores act as capillary tubes to draw the water, and as they fill, the capillary forces decrease along with the infiltration rate.

S.No.	Time (min)	Infiltration cm/day	Remarks
1	0-2	Erratic	Settling of infiltration process, stabilization of external influence
2	2-55	1.8	Varies between 0.8-3 cm/day with decreasing trend–influence of pumping?
3	55-60	Erratic	
4	60-420	2	Varies between 0-3.8 cm/day –stable
5	420-490	Erratic	Influence of pumping?
Test 2			
1	0-300	5.5-11.4	Influence of pumping?
2	300-850	4-5.6	Stable
3	850-900	8	Influence of pumping?

The groundwater recharge as seepage has also been computed based on lake water balance for different months.

Groundwater recharge rate based on aquifer parameters have also been computed. . For the computation the following parameters have been used. Aquifer thickness is considered as per the groundwater level fluctuations based on monitoring, effective porosity (K) is taken as 3.0m/day. and the average hydraulic gradient based on the ground water elevation slope and is considered is of .02 The lake water spread area that facilitates recharge for 49649.637 m2. Average recharge rate from the between end May(represented by deepest water level) to August (rising water levels) shows wide range varying from 40 cms/day to 29 cms till the end of August.

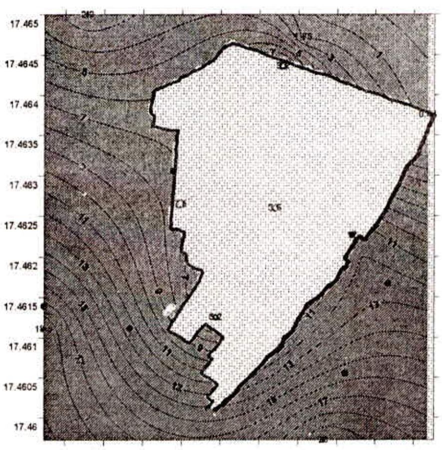
Based on the different computation it is clearly seen that recharge is not constant and is varying influenced by number of parameters including lake water column, aquifer lithology, permeability and groundwater development. Infiltration rate varies from negligible to as much 40 cms/day. The lake bed formation that facilitates such recharge has also been analysed and is found to be sandy loam.

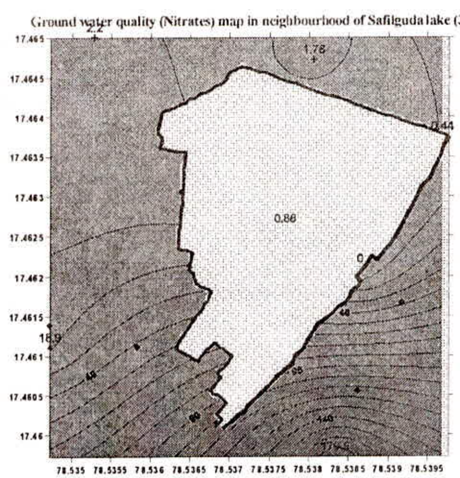
SIEVE ANALYSIS RESULTS:

Sieve Size	Results (%)	Soil Type
>500 microns	70.09	Sandy Loam
<500 microns	29.90	
<425 microns	18.37	
<250 microns	9.27	
<125 microns	3.33	

It is very clearly seen that infiltration from the lake bed is an important contribution to local groundwater system. The influence of the lake recharge is not uniform on all directions and is not the same all through the year. Seepage from the lake adds to the groundwater reserve in the influencing zone by raising the water levels. In some months of the year the lake receives groundwater into it through effluent conditions.

GROUNDWATER QUALITY MAPPING





The ground water recharge impact of the lakes in its neighborhood is also verified by the studying the groundwater quality in the wells. Study of nitrates contour map shows the lake water acts as a major source for dilution of nitrates. As one moves a way from the lake the nitrate values gets increased, and farthest from the lake the nitrate is the highest.

FINDINGS

The lakes and the local groundwater system around the lake are intrinsically associated in the Hyderabad study area.

- Recharge is facilitated by the lakes to the local groundwater system.
- The recharge entering the ground-water system is not uniform across the lake area.
- Recharge rates are different for different months.
- Rate of recharge varies from few cms/day to maximum of 40 cm/day.
- The rate of recharge is maximum of 40 cms/day in the month of May(represented by deepest water level) and gradually decreases to 29 cm/day July (rising water levels) and almost to nil when the lake receives inflows from the groundwater system.
- Recharge is generally limited when the regional water table is high and increases when the groundwater levels drop significantly in summer.
- As the groundwater extraction increases water level in the lake drops significantly. (In the case of safilguda the lake almost went dry in May 2005).
- Ground water recharge from the lakes enters the local flow system and travels for certain distances (maximum of 200-300m in the case of safilguda) depending on the lake water spread area and water column.
- The lake recharge supports inflows into the wells and bore wells.
- Polluted lake water significantly pollutes the groundwater quality.
- Amount of ground water moving through the flow systems can be easily quantified based on the lake water spread area, groundwater level fluctuations, effective porosity (K) and the average hydraulic gradient.
- The beneficial zones of recharge are the shallow aquifers in the weathered granites and fractured granites.
- The distribution of recharge is controlled largely by the regional groundwater gradient.

Table : The lake water level elevation

Lake Code	Well type	Lat	Long	28-Jan-2005	27-Feb-2005	25-Mar-2005	14-Apr-2005	11-May-2005	11-Jun-2005	14 -July-2005	12-Aug-2005
03	BW1	17.4611	78.5358	533.74	533.60	531.47	525.45	524.47	526.63	528.745	530.48
03	BW2	17.4597	78.5383	525.99	525.86	525.23	521.55	520.20	521.24	525.463	527.11
03	BW3	17.4606	78.5386	527.66	527.54	526.45	522.35	521.48	522.91	527.258	527.97
03	OW1	17.465	78.5353	530.90	530.77	529.10	523.22	521.78	523.32	529.545	531.52
03	OW2	17.4614	78.5347	530.07	529.91	528.14	524.16	523.20	524.92	530.48	528.55
03	OW3	17.4611	78.5347	528.24	528.07	526.59	522.15	521.42	525.10	528.27	530.14
03	OW4	17.4631	78.5364	532.82	532.59	531.13	527.65	521.06	526.27	530.245	531.82
03	OW5	17.4617	78.5392	527.27	527.11	525.47	522.55		523.39	527.135	528.37
03	OW6	17.4647	78.5381	532.07	531.88	530.43	526.85	526.01	524.81	531.898	533.26