Water Allocation Policy and its Implications in the Waikato Region

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ABSTRACT: The Waikato River is New Zealand's longest River, though relatively small on international scales. It drains the central North Island and has New Zealand's largest lake (Lake Taupo) at its headwaters. The upper reaches have sustained flows fed by large aquifers which are recharged by rainfall events providing relatively constant river flows, whereas the lower reaches respond more directly to rainfall events having more peaky flows after rainfall and extreme low flows during dry periods. Consumptive allocation from the river is relatively low with only about 3% of the mean annual flow being allocated. However, more than seven times the river's flow is allocated for non-consumptive purposes before discharging to the Tasman Sea. The majority of this non-consumptive allocation is for hydro power generation and as cooling water at both thermal and geothermal power stations which produce up to 25% of New Zealand's electricity. The upper half of the river has been heavily modified with the construction of eight dams for power generation. This has resulted in a succession of cascading dams replacing the previously uncontrolled river. The Waikato River also provides drinking water for Auckland City (NZ's largest city) and Hamilton City (NZ's 4th largest city). In recent years there has also been considerable growth in water requirements for pasture irrigation to support the intensification of dairy farming in the catchment. Operators of the power stations are concerned that any further consumptive allocation will further reduce their ability to generate electricity. The Waikato Regional Council, who is charged with managing the river and allocation of water, has recently set new rules for managing the conflicting allocation demands on the Waikato River. This has resulted in an end to further allocation of water where it results in a loss of water for electricity generation from renewable resources (fresh water and geothermal water). The exception to this is the prioritisation of water for municipal supplies ahead of other consumptive uses such as industries and irrigators.

1 INTRODUCTION

The Waikato River is in the North Island of New Zealand. It is the New Zealand's longest River, 425 kilometres in length, with its headwaters in the central North Island mountains, includes New Zealand's largest lake (Lake Taupo which is 611 km^2 in area), captures inputs from hill-country streams, rivers and springs, and drains lowland tributaries, lakes and wetlands down to the river's mouth at Port Waikato (near Auckland City). Precipitation distribution across the catchment is largely controlled by the westerly direction of the prevailing wind and by topography. Highest rainfall occurs at the head of the catchment in the mountains and ranges south of Lake Taupo. The catchment upstream of Hamilton is dominated by volcanic geology, where rainfall rapidly infiltrates into the soil, resulting in relatively subdued flood responses in streams and rivers. It also produces large groundwater stores which sustain stream and river flows during times of low rainfall. River flow in the upper Waikato catchment above Karapiro has been nearly fully utilised for hydro-power generation with eight hydro power dams and the primary hydro-power water storage being in Lake Taupo. Water is also taken for cooling of geothermal power stations and recently there has been a large increase in water demand for pasture irrigation of dairy farms. In the lower catchment, including the Waipa River, the older tertiary sediments have much lower infiltration rates, resulting in a river system that is much more responsive to recent rainfall. Consequently, the lower river experiences large flood peaks after storm events and low flows during periods of low rainfall. In the lower river there is no hydro power generation, water is primarily taken for city drinking supplies (Both Auckland and Hamilton Cities), cooling of a thermal power stations and pasture irrigation.

The allocation of water from the river is managed by the Waikato Regional Council. There is considerable conflict between the various users of the river in recent times as the availability of the resource has become scarce. Within a few months there will be no more water available for allocation in the River above Karapiro. The Council has capped the allocation at 5 per cent of the 1 in 5 year 7-day low flow (known as Q_5). This is equivalent to 7.4 cubic metres per second (m^3/s) of water available for consumptive allocation. All of the remaindering flow must remain in the river to be used for hydro power generation. In the lower river below Karapiro the allocation limit is set at 10 per cent of the Q_5 which is equivalent to 18.8 m^3/s. This water is likely to be fully allocated within the next year. The remainder of the water remains in the river to maintain the health

and well being of the river. This is primarily to maintain water quality where further allocation of water would result in further degradation of the water quality which is not acceptable.

This paper describes the catchment hydrology, the users of water and the rules which govern the allocation of water.

2 RAINFALL

There are three long-term rainfall records with over one hundred years of record; one at the head of the catchment (Taupo), one in the middle (Ruakura near Hamilton City) and one at the mouth (Waiuku near Auckland City). Rainfall data has also been measured in at least 85 other locations, but with much short records. These include manual daily rainfall and automated sites that provide a fairly evenly-distributed network across the catchment.

Rainfall in the Waikato catchment is strongly controlled by the prevailing westerly wind and topography. Greatest annual rainfall occurs at the head of the catchment on the central North Island mountains and on the western and eastern ranges of the Lake Taupo catchment. Annual rainfall is generally lower in the northern areas of the Waikato catchment through the Hamilton Basin near the mouth of the River.

Analysis of the three longest records (Waiuku, Ruakura and Taupo) over the past 100 years shows no significant long-term change in annual rainfall. That is, the catchment was not getting drier or wetter over this time. However, there are obvious cycles of wetter and drier years, as well as extremely large variations from year to year. For example, in the middle of the catchment near Hamilton, the average annual rainfall was 1,150 mm and has varied between 820 mm (in 1932) and 1,650 mm (in 1924). As shown in Figure 1 there is a general trend of greater than average rainfall in the years from 1950 to 1980, coinciding with a negative Interdecadal Pacific Oscillation phase and less rainfall recorded from 1910 to 1945 and from 1980 to 2008, coinciding with positive Interdecadal Pacific Oscillation phases.

Monthly rainfall totals for the Waikato catchment have a pattern of highest totals during winter (peaking in July) and lowest during summer, with the minimum usually in the month of February. The median rainfall in February is normally about half that recorded in the month of July. However, the rainfall within each month can be highly variable, and the maximum monthly rainfall often has no seasonal pattern.

Monthly rainfall totals are not strongly influenced by short duration—typically 3 to 5 years—climate signals such as the Southern Oscillation Index and the associated El Nino and La Nina phases.

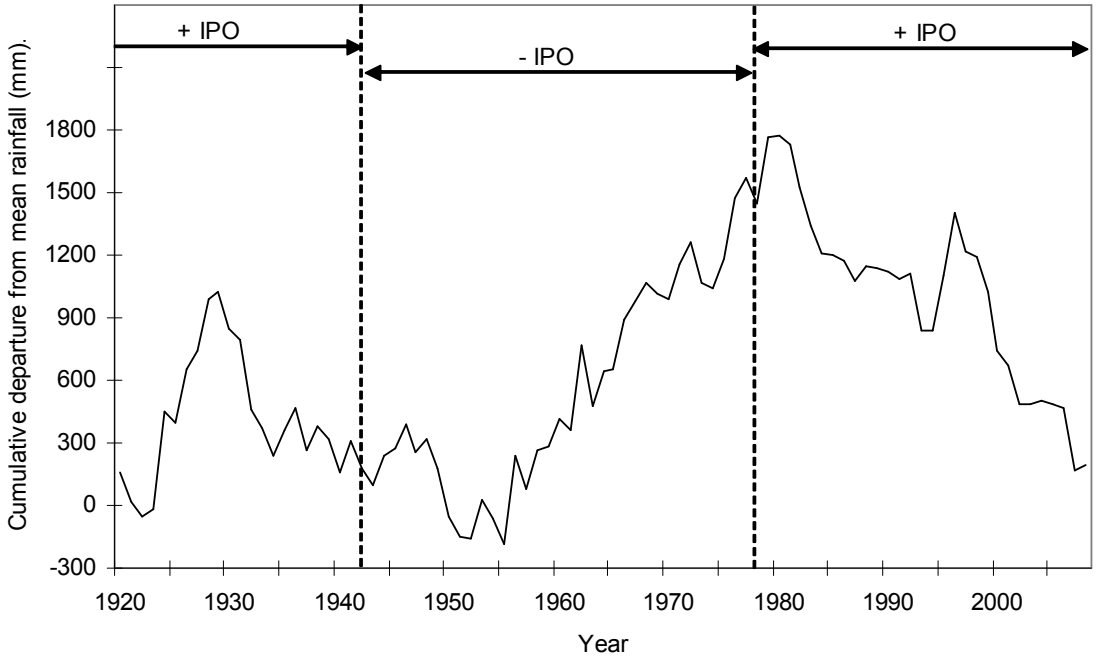

Fig. 1. Rainfall (near Hamilton City)—cumulative departure from mean annual rainfall—and years influenced by positive and negative Interdecadal Pacific Oscillations (IPO).

3 GROUNDWATER

Most streams in the Waikato are perennial, with substantial groundwater discharges providing sustained baseflows during periods of low rainfall. For a number of the Waikato hydro-lake catchments, the groundwater input is substantial and dominates the flow regime of these streams. The geology of the Taupo and hydro-lake catchments consists of porous pumice, volcanic ash and ignimbrite which absorb much of the rain, leading to large groundwater reserves and steady spring-fed baseflows for the streams (Mighty River Power 2001). In the Torepatutahi Stream in the Ohakuri Dam catchment, groundwater discharges account for 70% of the stream's annual flow (Piper 2005).

The importance of the large storage of groundwater and the associated groundwater discharge to streams was illustrated during the recent 2007–08 summer. Streams without groundwater inputs such as the Waipa and lower Waikato tributaries recorded extreme low flows that on average only occur once in every 80 or more years (1-in-80 year return period). However, the groundwater baseflow dominated streams of the catchment above Karapiro and Lake Taupo maintained and recorded much higher summer low flows that typically occur once in every 2–5 years.

Careful management of groundwater abstractions from shallow aquifers or aquifers linked to streams, such as those in Pukekohe (near Auckland City) and upstream of Karapiro, is needed to ensure spring flows do not reduce. For the past 20 years groundwater users in the Pukekohe area have been directed into the deeper Kaawa sandstone aquifer rather than the shallow basalt aquifers (Hadfield 2001). As a result, groundwater users have access to water and the stream's baseflow from the shallow aquifers is maintained to meet the instream ecological requirements.

In the catchment above Karapiro the groundwater resource is highly connected to the surface water. Water balance analysis indicates that nearly all of the groundwater eventually discharges to the Waikato River upstream of Karapiro Dam. As a result any allocation of groundwater will result in a loss of water to the river of the equivalent volume.

3 FLOW REGIMES

3.1 Tributaries

There are 10 major tributaries to the Waikato River with average discharges ranging from 1.5 m^3/s to 90 m^3/s. Together, the average flow contribution of these 10 tributaries is 135 m^3/s, or 30% of the total average flow of the River at its mouth (approximately 450 m^3/s). By far the largest tributary is the Waipa River (at Whatawhata) which contributes an average flow of 90 m^3/s; the next largest is Mangakino contributing 11.4 m^3/s. During flood-flows the peak discharge from the Waipa catchment can contribute between half and two-thirds of the flow in the lower river, even though it only drains 20% of the total catchment area (Mighty River Power 2001).

3.2 Flow Description

Flow duration curves are presented for key locations in the Waikato catchment (Fig. 2). The flow duration curves for the two sites on the mainstem of the river (Hamilton and Rangiriri) have a similar shape, while that for the Waipa River (Whatawhata) differs markedly. The curves for the mainstem sites indicate a flow regime with sustained baseflows during low flow periods and subdued flood peaks during storm events. This flow regime can be largely attributed to the geology of the Waikato catchment above Karapiro which has large groundwater stores, while the surficial pumice sediments permit rapid infiltration of rainfall. The much steeper flow duration curve for the Waipa catchment is attributable to its siltstone geology which has much lower infiltration rates and smaller groundwater reserves for sustaining stream flows during periods of low rainfall. On the mainstem downstream of Hamilton City the reduced influence of the upper catchment's volcanic geology, and the increasing influence of the lower catchment's tertiary siltstone and mudstone geology, results in duration curves with larger specific flood discharges and lower baseflow discharges as the river gets closer to the mouth (e.g., Rangiriri; Fig. 2).

The Waikato River has a monthly pattern of highest flows in winter and spring (June to November), and lower flows in summer and autumn (December to April). This pattern is apparent along the entire length of the river and in the un-dammed tributaries. Downstream of the Waikato hydro-system the median summer discharge at Hamilton is typically in the order of 210 m^3/s and increases to 300 m^3/s during winter.

Discharges at Ngaruawahia (downstream of Hamilton but upstream of Rangiriri) represent the combined Waipa tributary and Waikato flows where there is less influence of the hydro management and the large groundwater discharges. The summer flows are in the order of 250 m^3/s increasing to around 400 m^3/s in winter. The influence of the Waipa River on flows at Ngaruawahia is most pronounced at higher discharges (75^{th}- to 100^{th}-percentile). This is represented by the highly variable nature of these discharges at Ngaruawahia compared to Hamilton.

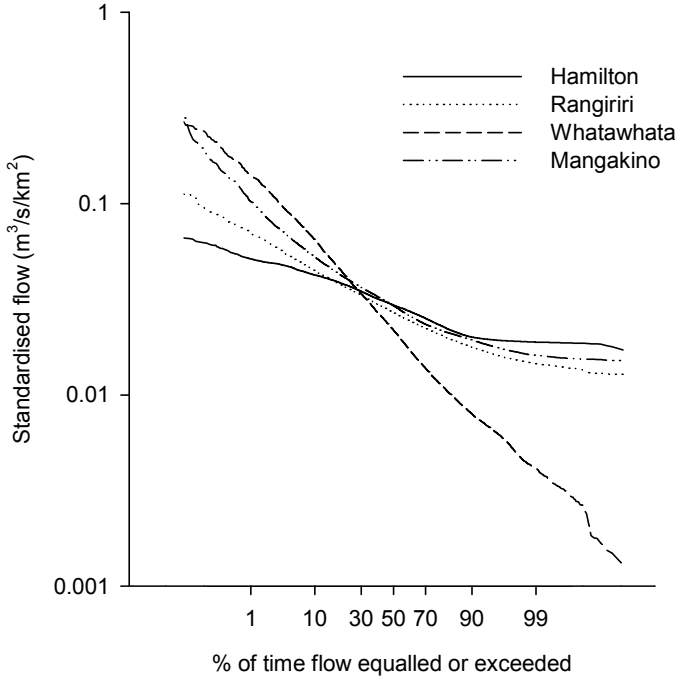

Fig. 2. Flow duration curves for four key locations in the Waikato catchment.

3.3 Low Flows

When allocating water, a portion of the 1 in 5 year 7-day low flow (known as Q_5) is provided for consumptive allocation and the remainder of the hydrograph for environmental flows, including meeting the instream ecological needs of the river and adjacent water bodies and power generation. The 1-in-5 year return period is chosen as it provides a high reliability of water availability with the likelihood of restrictions on consumptive users being on average only once in every five years. For the Waikato catchment the Q_5 flow increases from 50 m^3/s at Taupo Gates to 148 m^3/s at Karapiro Dam and to 188 m^3/s at the mouth of the Waikato River.

The greatest in-flows during low-flow conditions occur in the catchment above Karapiro, including Lake Taupo. Specific water yields upstream of Karapiro during low flows are typically greater then 0.015 $m^3/s/km^2$. The specific yields decrease markedly in the lower catchment to 0.006 $m^3/s/km^2$ (Table 1). This decline in sustained low flow discharge in the lower river is also apparent in the flow duration curve for the Waipa River which shows a steep decline in the tail of the curve (Fig. 2). Low flows in the lower Waikato River (Rangiriri) are therefore primarily sustained by the upper catchment.

Table 1. Seven-day 1-in-5 year low flow statistics for the Waikato River

	Cumulative flows and area			Individual flow and area		
	m^3/s	km^2	$m^3/s/km^2$	m^3/s	km^2	$m^3/s/km^2$
Taupo out-flow [a]	50	3,289	0.015	50	3,289	0.015
Waikato River at Karapiro Dam [a]	148	7,852	0.019	98	4,563	0.021
Waikato at Ngaruawahia (includes Waipa)	169	11,395	0.015	21	3,543	0.006
Waikato River at mouth	188	14,444	0.013	19	3,049	0.006

[a] influenced directly by hydro system minimum flows and consent conditions

3.4 High Flows

Problems with flooding are largely restricted to the low elevation plains of the lower Waikato and Waipa Rivers. Flood peaks in the Waikato River above Hamilton are largely contained within the incised stream channel or are controlled by the storage capacity of Lake Taupo and the hydro-dams (Ridall 1979). Construction of the Lower Waikato Waipa Flood Control Scheme began in 1961 in response to a number of large floods in the 1950s. When major flooding occurs in the lower Waikato River downstream of Hamilton, it is generally due to heavy rainfall in the western parts of the catchment, particularly over the Waipa catchment. In the July 1998 flood the peak flow at Ngaruawahia was 1,487 m^3/s and of this 807 m^3/s (54%) was from the Waipa catchment, even though the Waipa catchment only covers 25% of the catchment area above Ngaruawahia (Mighty River Power 2001).

3.5 Hydro-electricity Diversions

At the head of the catchment is the Tongariro Power Development (TPD) consisting of three power stations. The TPD has several sources of water, comprising water from the Tongariro River that would naturally have entered the lake, and water import from outside the Waikato catchment via the Eastern and Western Diversions which comprise of a number of canals and aqueducts. On average the scheme imports about 30 m^3/s of "foreign" water from outside the Waikato catchment. The water that is imported has valuable electricity potential as once it is in Lake Taupo it is available for further generation at the hydro-dams on the Waikato River.

The Waikato River hydro-system consists of the Taupo control gates, eight hydro-dams and nine power stations—two power stations on the Maraetai Dam. Installation of the Taupo Gates in 1941 changed the Waikato hydro-system from being run-of-river to having short-term control over storage and enabling the matching of power generation times to demand (Mighty River Power 2001). The combined peak generation from these hydro-dams is 1,100 MW.

4 WATER ALLOCATION

Nearly all of the water allocated or used in the Waikato catchment is returned after use and available for further allocation downstream. This can include water passed through hydro-power turbines where all the water taken is returned. The majority of other activities return a large portion of the water taken directly back to the river after it is used. These are termed partially consumptive takes. For example, most of the water taken by some municipal water supplies and industries for cooling is returned to the river after use. The remaining activities account for the water which once taken is no longer available for further allocation downstream. These are termed consumptive takes. For example, water abstracted for irrigation is classified as being consumptive as the amount of water that may be returned is uncertain and there is a long delay from the time the water is taken to when there may be a return.

The total amount of water allocated (including power station diversions) in the Waikato catchment exceeds 2,900 m^3/s (equivalent to 250 million m^3/d). The average discharge of the Waikato River at the mouth in comparison is only 430 m^3/s. This means that, on average, each drop of water is used more than seven times before flowing out to sea. The total amount of water allocated for consumptive and partially consumptive uses is much smaller, being approximately 70 m^3/s. Much of this water is used for cooling at Huntly and Wairakei power stations with nearly all the water, except that lost as steam being returned after use. The total consumptive

component of these uses is approximately 13 m^3/s, equivalent to only about 3% of the river's average discharge. In the Waikato catchment water is allocated to four water-use sectors, these are; municipal and domestic water supplies, agriculture and horticulture for irrigation, industries (including power generation) and recreation. Recreational consumptive use is very low, and includes takes for golf courses, pools, gardens and sports grounds irrigation.

Domestic water supplies for both urban and rural communities are the largest consumptive water-use sector in the catchment with a combined allocation of about 5 m^3/s, or 41% of all the consumptive water use in the catchment. Seventy percent of this domestic water is taken in the catchment downstream of Karapiro. The largest individual abstraction is Auckland's Waikato River take at Tuakau (Mercer to Mouth catchment) of up to 1.7 m^3/s. This consumptive take is likely to increase in the future to meet any increase in Auckland City's water demand. The next largest net take is for Hamilton's water supply of 0.7 m^3/s (noting that treated wastewater from the city is returned to the river).

Irrigation water is primarily used in the agriculture and horticulture sectors. The first irrigation consent in the Waikato catchment was granted in 1970. Since this time, demand for irrigation water has increased markedly, particularly for pasture irrigation. Peak summer demand is in the order of 5 m^3/s. The demand for irrigation water is extremely variable during the irrigation season and is typically equivalent to 60% of the consented rate, due to there being sufficient rainfall for much of the time. The majority of the takes for irrigation are from tributaries of the Waikato River.

There are five main sectors of industrial water use in the Waikato catchment, namely timber and paper processing, quarrying and mining, steel production, food processing and electricity generation. The total consumptive water use for these industries is about 2.9 m^3/s.

4.1 Water Allocation Rules

The Waikato Regional Council, who is charged with managing the river and allocation of water, has recently set new rules for managing the conflicting allocation demands on the Waikato River. The new rules first proposed in 2006 have finally past their last legal challenge and became operative on 10th April 2012. The process included many facilitated workshops and two hearings, the first hearing in 2008 and the second in 2011, each hearing approximately 9 weeks long.

In the catchment above Karapiro Dam the main conflict centered on who should get access to the water; power companies and the Council held the position that there should be no further consumptive allocation beyond current levels and rest of the water should remain in the river for renewable power generation. This position was supported by the Government's strategy for power generation which set a target that 90 percent of New Zealand's power generation should be from renewable resources by 2025, currently only 65 per cent is from renewable resources. The evidence presented in the hearings showed that there are few opportunities for new large scale hydro generation development in the Waikato Region and any further loss of water to consumptive allocation would reduce the current level of generation and reduce the likelihood of meeting the Government's 90 percent target. Other parties at the hearing particularly the agricultural sector held the position that significantly more water should be made available for consumptive allocation. The agricultural sector proposed an increase from 3.6 percent of the Q_5 flow (equivalent to 5.3 m^3/s), the current level of allocation, to 15 per cent (equivalent to 22.2 m^3/s). The Q_5 flow if 148 m^3/s.

The eventual decision from the last hearing in 2011 was an increase from 3.6 percent (5.3 m^3/s) to 5 percent of Q_5 (7.4 m^3/s). This was to provide for a small degree of growth in the agricultural sector, particularly for irrigation, while preserving the majority of water for power generation. Within one day of the hearing decision becoming public the increase in allocation (2.1 m^3/s) was taken by one user and the catchment upstream of Karapiro Dam is now fully allocated. No further allocation of water can now occur unless it is for the purposed of domestic or municipal water supply. If further allocation to a municipal supply results in the combined allocation of all water takes exceeding 5 percent of Q_5 there are 'claw back' provisions in the rules. These rules enable the reduction of water allocated to industrial or irrigator takes so that allocation remains at 5 percent.

In addition consents to take water will only be given a duration of 15 years, after which they must be renewed. If the catchment is over allocated consents may not be renewed or may be replaced for a lesser amount.

In the catchment upstream of Karapiro Dam groundwater is not a viable alternative to surface water takes unless it can be demonstrated it is not connected to the surface waters. As discussed earlier the water balance analysis indicates that nearly all groundwater eventually discharges to surface water.

In the lower river any change to the allocation limits must be done in a co-management arrangement with the indigenous people of New Zealand (Maori), in particular Waikato Tainui. Waikato Tainui has been give co-

management of the Waikato River as part of their grievance settlement with the Government for historical loss of land and water. Waikato Tainui is after an improvement in the holistic health and well-being of the River. Tainui's co-management settlement is the guiding principle for any future decision about how much water can be allocated from the river.

5 SUMMARY

The Waikato catchment is fortunate to have very good rainfall information. There are three long-term rainfall sites with records covering the past 100 years. Over this time there has been little change in the long-term trend in annual rainfall. However, the catchment's rainfall is influenced by shorter cycles of wetter and drier years linked to the Interdecadal Pacific Oscillation (IPO) climate cycle. This has resulted in below average rainfall for more than two decades since 1980. The IPO has recently changed phase and the catchment can expect above average rainfall for the next few decades.

Most streams in the upper Waikato catchments above Karapiro are perennial, with substantial groundwater discharges providing sustained baseflows during periods of low rainfall. The dominance of groundwater input decreases downstream of Karapiro and in the Waipa catchment.

Development of the catchment for hydro power generation has resulted in some major engineering works and modification of the river's hydrology. This includes in 1941 the construction of the Taupo out-flow gates. These gates changed the Waikato River from being run-of-river to having short-term storage control. There has been the construction of eight dams and nine power stations on the Waikato River which provide approximately 15% of New Zealand's electricity. This has changed the river above Karapiro into a series of lakes with little of the natural river channel remaining. The storage capacity of these lake results in a river with its daily flow regime largely controlled by the temporal demand for electricity. The river's flow is also augmented by an additional 30 m^3/s of foreign water via the Tongariro Power Development.

On average, each drop of water discharging out to sea at the river's mouth has been used more than seven times. This is primarily for hydro power generation or as cooling at other major thermal power stations. The consumptive allocation used for agriculture, municipal supplies and industry is approximately 13 m^3/s, equivalent to only about 3% of the river's average discharge (450 m^3/s)

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